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ELECTRICITY, ITS APPLICATION IN MEDICINE. by WELLINGTON ADAMS, M.D.

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"A Modern Night-Call."

ELECTRICITY

Its Application in Medicine and Surgery.

A Brief and Practical Exposition of Modern Scientific Electro-Therapeutics.

— BY —

WELLINGTON ADAMS, M. D.,

Author of "Art of Telephony—By Whom Discovered;" "Evolution of the Electric Railway;" "Design and Construction of Dynamo-Electric and Electro-Dynamic Machinery;" Lecturer on Electro-Therapeutics, University Medical College, Kansas City; Formerly Professor of Diseases of the Ear, Nose, and Throat, Medical Department, University of Denver, and Editor "Rocky Mountain Medical Review."

VOLUME II.

1891.
GEORGE S. DAVIS,
DETROIT, MICH.

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This little book is, by permission, respectfully dedicated to

FRANCIS E. NIPHER,

Professor of Physics in Washington University, whose unselfish devotion to the cause of science has commanded the author's admiration and respect.

VOLUME II.

CHAPTER I.

FORMS OF ELECTRIC MACHINERY AND THEIR APPLICATION.

Electro-Static Induction Machines are designed for the production of currents of extremely high electro-motive force and very small volume. They are all constructed upon the principles involved in the production of what has been called "*Frictional*" or "*Static*" *electricity*, although these terms are both too narrow and restricted for the accurate designation of the involved phenomena. The term *frictional* has been used because friction is one of the principal agencies by which this character of electricity is generated; while the term *static*, from the Latin *sto*, "to stand," has been adopted because this character of electricity is generally stationary. But it is neither always generated by friction nor always stationary. It may be generated in other ways, and it may flow just like any other form of electricity, and is subject to the same laws with respect to electro-motive force, resistance and volume. The

peculiar and special phenomena involved in its manifestations may be demonstrated by reference to Fig. 1, which illustrates the pith-ball electroscope. A horizontal brass arm is here mounted upon an ebonite insulating stand. From this arm two pith balls are suspended by silk threads, considerable space intervening between them. If a stick of sealing-wax

Fig. 1—The Pith-Ball Electroscope.

be now electrified by friction with a silk-handkerchief, and brought near one of these balls, the latter will be attracted to the wax, and, after a momentary contact, repelled. If followed up with the wax, it continues to recede as if pushed back by some invisible power. If the other ball be now approached to the first one, both will be attracted to each other, and, after contact, repelled, the suspending threads showing a

divergence in each direction. If the electrified wax be again brought near, both balls will be repelled by it; but if a non-electrified body be brought near the balls, they are attracted to it. If each of the balls be separately electrified by the wax, and then brought near each other, there will be mutual repulsion without previous attraction.

From this series of phenomena it is demonstrated, first, that bodies may be electrified by *friction*; second, that they may be electrified by *induction*, or by close proximity to bodies already electrified; third, that electrified bodies not only attract non-electrified bodies, but communicate electricity to them by contact; and fourth, that bodies similarly electrified, either by each other or from the same source, show mutual repulsion.

These phenomena constitute the underlying principles involved in the construction of all frictional and influence machines, and in the manifestation of what is called *static* electricity. The terms used to distinguish the different clases of electric phenomena, as *Frictional*, *Static*, *Galvanic*, *Chemical*, *Magnetic* and others, originate from the different methods by which electricity is generated, and the varied conditions under which its phenomena have been observed, and must not be understood as referring to any difference in the nature of the electricity produced.

A static machine is simply an aggregation of

electrical and mechanical elements for the generation, collection and conservation of a series of just such electrical changes as were produced on rubbing the sealing-wax. The first machines of this class operated upon the principle of friction purely, were

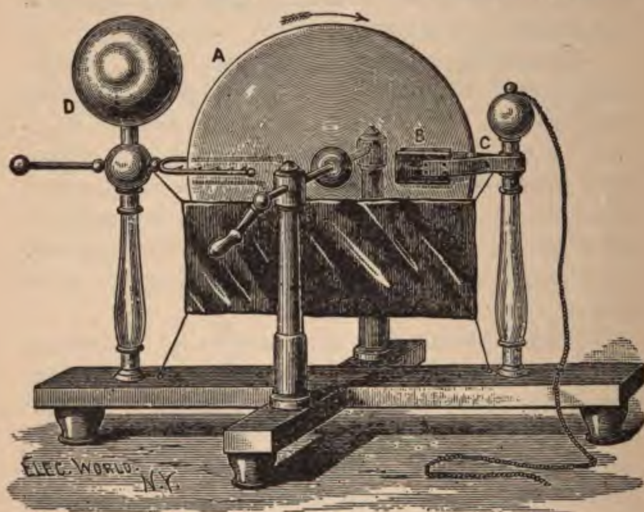

Fig. 2—Plate Electrical Machine.

known as "frictional" machines, (see Fig. 2), and which shows one of the earlier forms invented about 1787.

Prior to 1865, frictional machines were the principal electro-static generators in use. That year, however, brought great progress, in the shape of the

invention of two new machines of remarkable energy and efficiency.

First came the Holtz machine, shown in Fig. 3, which is purely an *influence* machine, operating upon the principle of *induction*, being constructed with two

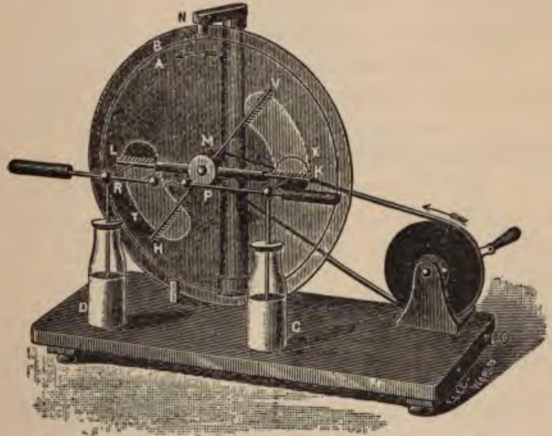

Fig. 3—The Holtz Electrical Machine.

glass plates arranged to generate electricity by their mutual inductive influence. This machine had to have an initial charge placed upon the "*inductors*" (T. X.) on the back or stationary plate, every time it was to be used. This charge acted inductively upon the front or revolving plate with increased force, and

this again reacted upon the back plate with still greater force, this cumulative and reactive action continuing till a charge of very high potential resulted. Next came an improvement by Töpler, which, in the main, consisted in an arrangement for making the machine self-charging and cumulative like the modern *dynamo* or electric light generator. A modern form of this machine is represented by Fig. 4. This improvement was brought about by the mounting of six little round metallic caps or "*carriers*" (c. Fig. 4) upon the front or revolving plate, and the provision of two metalic brushes (a. b. Fig. 4) to rub against these carriers. These "*brushes*" rub against the "*carriers*" when the front plate is revolved, and generate an initial charge, which is conveyed to the *inductors* (A. B.) upon the back or stationary plate, and thus *charge* the otherwise Holtz machine, which then continues the action in the manner already described when speaking of the latter machine.

The Töpler generator constituted a great advance in the evolution of static machines, and in all the years that have followed its introduction, but little in the way of an *electrical* improvement of this machine has been inaugurated, although the Wimhurst machine (see Fig. 5) which has very recently made its appearance, is claimed to be something of an improvement over it.* This machine consists,

*This machine has been placed upon the market by the Electrical Supply Co., of Chicago.

primarily, of two revolving glass discs, placed near together, each having an equal number of metallic sectors or "*carriers.*" These discs revolve in oppo-

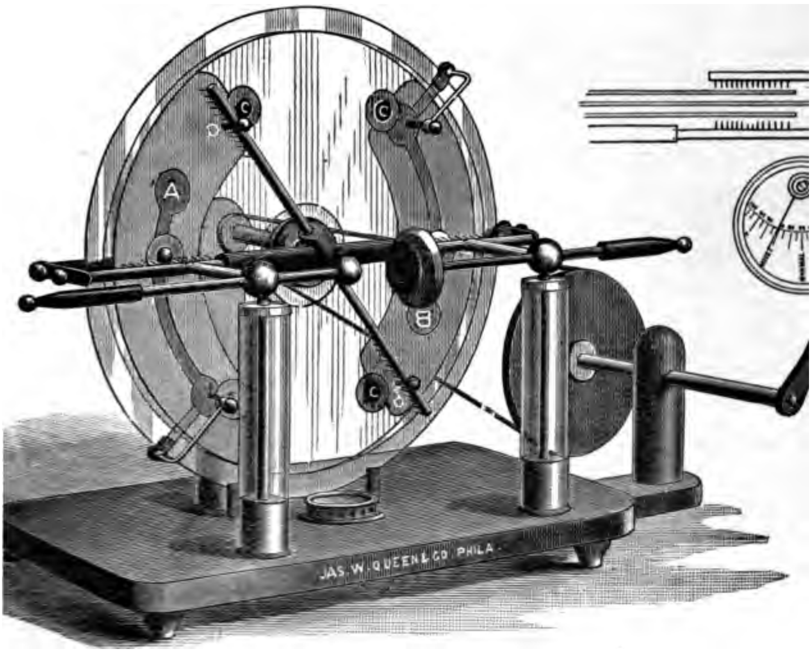

Fig 4—The Modern Töpler Machine.

site directions, and are enclosed between two stationary glass plates firmly set in the frame, which protect the generator from injury, dust, and moisture. The

latter seems to be the principal feature which is relied upon to constitute an improvement, and we very much question whether this does not constitute a decided disadvantage rather than an improvement, since a certain amount of dust and moisture is bound to enter through the openings for the belts, and when once there is with difficulty removed,

Fig. 5—The Wimhurst Machine.

the whole machine having to be taken apart. It is best to have a covering for the entire machine, which can be quickly and conveniently removed, as in the case of the cabinet shown in Fig. 28.

Although not improved much *electrically*, the Töpler machine has, however, been greatly improved *mechanically*, and in its *adaptation to ·he requirements of the medical profession*, by Prof. Philip Atkinson, of

Chicago, whose machine, is manufactured by the Mc-Intosh Battery Co. of the same place.*

This machine is admirably constructed mechanically, and after a careful investigation and an extended practical experience, the writer unhesitatingly pronounces it the *cheapest*, and at the same time the *best*, machine upon the market for the purposes of the electro-therapeutist, because:

It is neat and compact, occupying but little space:

It generates as high an electro-motive force as many other forms of machines of from two to four times its size, and which frequently occupy more space that the whole cabinet illustrated in Figs. 27 and 28:

It does not get out of order readily, because of its superior mechanical construction:†

It is provided with a simple, convenient and effective means of tightening the belt when this becomes loose:

Its construction is such that it may be easily and quickly taken apart for cleaning:

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*To those who wish to make a thorough study of static electricity, the author recommends the reading of Atkinson's book on this subject, published by W. J. Johnston of New York.

† This might be still further improved upon by the substitution of *longer* bearings or journal boxes for the shaft which carries the driving wheel. In ordering, demand this improvement.

It will generate a current *nearly* every day out of the year, when properly cared for, only failing two or three days out of the month, during the two hottest summer months:

It picks up its charge and begins to generate very quickly:

It runs *very* easily and smoothly, requiring but little power:

Fig. 6—Atkinson's Improved Töpler Machine.

It is provided with a very superior and convenient method of securing the "*induced*" current, which produces physiological effects similar to the Faradic current:

It will, when in good order, produce a spark equal in length to the radius of the revolving wheel:

It is not so large as to entirely preclude the possibility of its being taken to the bedside; and

the future will find this frequently done, for the purpose of facilitating convalescence from low types of fevers, through the superior tonic influence of static electrizations:*

Its peculiar and superior mechanical construction adapt it to be run by either hand or some form of mechanical power, which is not the case with some others.

A static machine is nothing more nor less than a device for dynamically producing what is chemically produced in a Galvanic battery—that is, a *difference of potential.* In the case of the static machine, the difference of potential is very high, (over 60,000 volts) and yet the resulting current is very small, because the internal resistance of the machine is very high, (millions of ohms) while in the case of the Galvanic battery, the difference of potential is comparatively low, (from 1 to 2 volts), but the current large, because the internal resistance is likewise comparatively low (from ½ to 5 ohms). But *so-called*

* It is, however, to be hoped the future will see the development of still more portable and less fragile machines of equal power, that could be as readily carried to the bedside as a Faradic battery, and we see no inherent reason why this should not be capable of accomplishment. The introduction of such a machine should give an unparalleled impetus to the use of high potential currents for therapeutic purposes. It is indeed possible the writer may himself produce such a machine in the near future.

static electricity nevertheless has *volume*, and *flows* just as much as any other form of electricity. The author was the first in *this* country,* so far as he knows, to demonstrate the fact that, if the two combs of a Holtz machine be connected with the poles of a second similar one, which is then set in action, the plate of the first machine will begin to rotate. Here, then, the electricity generated by one machine *flows* to the second machine, and thus transmits the motion of the second to the first machine, the one expending what the other produces. In this experiment, the two machines are connected by *opposite poles*, the system constituting a "*circuit*," which is traversed in a *definite direction* by a *continuous electrical current*. Static electricity, therefore, possesses all of the characteristics of a Galvanic current,—volume and tension; manifesting polarity, with its distinctive effects, flowing in a definite direction, and being either continuous or intermittent. It can decompose water; produce mechanical power; produce physiological, as well as luminous and heating effects; magnetize, iron and steel; produce chemical changes, such as the separation of iodine from the potassium salt in iodide of potassium; and, in fact, do everything that

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*See paper read by the author before the Civil Engineers Club of St. Louis, April 23, 1884. The demonstration was, however, first made in the presence of Prof. Francis E. Nipher, in 1883.

can be done by a Galvanic current,* *only not to the same extent*, because, as explained, the strength or volume of its current is small. On the other hand, however, its pressure is great, so that it may reach organs and parts that could not be reached by the Galvanic current, and hence its small volume will often do more good than the large volume of the Galvanic current which may never reach the seat of trouble; on the same principle that an ounce of powder in the hands of a brave man who will carry it to the seat of war, will prove more effective, than one hundred pounds in the hands of a coward who has not the courage to reach the battle ground.

Currents from static machines may be either *continuous* or *intermittent*, but their volume is of *necessity* very small, and may, therefore, be neglected in all measurements. The pressure or difference of potential, however, is a very important factor which may be varied, and can be measured The author has designed a novel, direct-reading electrometer, Fig. 7; which will be found to be a very serviceable instrument for this purpose; it should be mounted directly upon one of the poles of the machine. Its use will undoubtedly help to place this branch of electro-therapy upon an advanced and more scientific basis,

*We expect these statements will prove somewhat dumbfounding to those accustomed to reading current works on electro-therapeutics. But the author is prepared to meet all controversies in the journalistic forum.

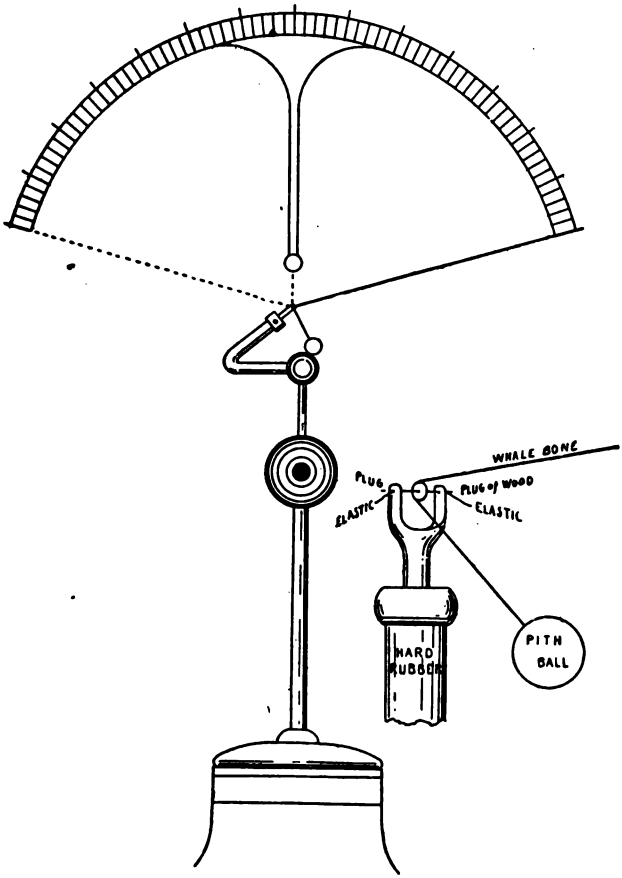

Fig. 7—The Author's Direct-reading Electrometer.

and furnish a means of studying the causes for the capricious action of static machines. The strength or volume of the current produced by these machines is nearly proportional to the velocity of their rotation. The electro-motive force or pressure, however, is independent of the velocity of rotation, (about 53,900 volts at all speeds) but diminishes as moisture increases. The internal resistance dimminishes rapidly with increased velocity of rotation (2810 million ohms at 120 revolutions per minute, and only 646 million at 450 revolutions). The deleterious *effects* of moisture are decreased by spreading beneath the machine a few drops of petroleum. The *presence* of moisture may be largely avoided by the use of a saucer of anhydrous chloride of calcium, or of sulphuric acid, placed in the case with the machine.

In the Atkinson machine, the upper pole to the left, connecting with the inside of the Leyden jars, is the positive one; while the lower pole, to the left in the base, connecting with the outside of the jar, is negative. It will generate only when being revolved in one direction—to the left when facing the front of the machine. It should be insulated from the table on which it stands, by means of inverted glass tumblers coated with shellac. The table supporting the machine should also be insulated from the floor by placing glass telegraphic insulators, coated with shellac, upon the legs. The table should stand as far away from the walls of the room as possible, never

nearer than one foot, and should be located in as large a room as possible, preferably in a south room and in front of a south window. When in daily use the machine should be thoroughly cleaned with a silk handkerchief every morning, catching the handkerchief by the ends and passing it back and forth between the plates and over the outside surfaces front and back. Attention to these little details will greatly enhance the generating power of the machine at all times, as well as cause it to be operative the greatest possible number of days out of the year.

The medical uses and methods of applying the currents derived from static machines, will be discussed in another place.

Fig. 8—Two-point Switch.

Switches will give an operator an unparalleled amount of trouble, and cause hidden defects that are sometimes very perplexing and difficult of detection, unless properly constructed in the first place. Each lever (D, Fig. 8) of a switch should have a separate

contact spring beneath it, the pressure of which against the contact point can be conveniently adjusted by the physician. The central pin (A, Fig. 8) of the lever should also have an arrangement for tightening from the *outside*. Switches containing these elements are to be found upon the DuBois-Reymond coil manufactured by the Law Telephone Co.* Switches are made with one, two, three or more points, according to the purposes for which they are designed. Fig. 8 shows a two-point switch, mounted upon a hard-rubber base; the current is led in at A and out through the point B or C, according to the position of the lever D. Switches of this character are used in the author's cabinet in the manner diagrammatically shown at 1, 2, 3 and 4 in Fig. 29. In Fig. 29 1 and 4 are three-point switches, 3 is a two-point, and 2 a four-point switch.

Pole-Changers are calculated to give even more trouble than simple switches, when constructed in the ordinary manner shown in Fig. 9. These must likewise be provided with adjustable contact springs beneath the levers, and with means for tightening up

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*The switches shown in Figs. 8 and 9 are devoid of these elements, being introduced for the purpose of showing the difference between properly and improperly constructed ones. A pole-changing switch possessing these elements is, however, shown in Fig. 10, as constructed by Mr. Gaiffe of Paris; a a indicates the adjustable contact spring, and b, the tightening screws for the levers.

the central pins of the levers from the *outside*, so as not to have to remove the entire switch and connections from the table every time a loose contact is observed.

Fig. 9—Pole-Changer.

In this device, the positive and negative poles are connected respectively with A and A, while the contact points 1 and 4 are connected together, and the same with 2 and 3. The point 1 is connected

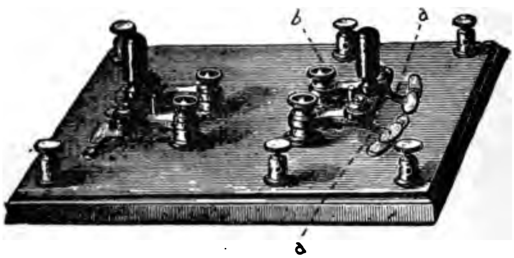

Fig. 10.

with one binding-post, and the point 2 with the other. The movement of these levers from right to left, and left to right, will thus change the poles connected with the binding-posts. These connections are diagram-

matically shown at 5 in Fig. 29 and at A B C, in Fig. 11.

THE CURRENT ALTERNATOR, REVERSER AND COMBINER, is made up of two pole-changing switches of the kind just described. It is illustrated in Figs. 10 and 11, the latter giving a diagram of the connec-

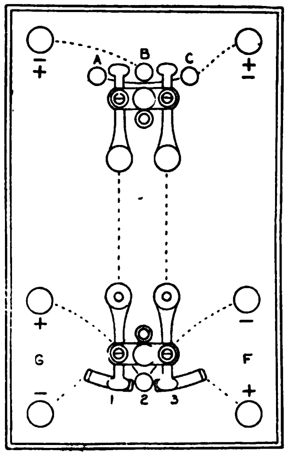

Fig. 11.

tions. Two pairs of posts (G. and F.) receive the wires from the poles of the Galvanic and Faradic batteries respectively. When the springs rest upon 1 and 2, the Galvanic current alone circulates, and when upon 1 and 3, as in the diagram, the Galvanic current passes through the secondary wire of the induction coil, and then through the subject in-

cluded between the binding posts $\pm$ and $\pm$. Thus superimposing the Faradic current upon the Galvanic current, allowing both to be used at one and the same time. With this apparatus, therefore, we may from one pair of binding posts, secure either the Galvanic or Faradic currents, or both currents combined; and we may reverse the direction of either the Galvanic or Faradic, or of both combined. The advantage of being able to pass immediately from the Galvanic to the Faradic current without removing the electrodes is very great, especially in electro diagnosis, whilst the operation of "Galvano-Faradization," which we are thus enabled to practice quickly and conveniently, is one of great therapeutic value. DeWatteville is the author of this idea. Waite & Bartlett, of New York, manufacture such a switch.

An Audible Indicator, to make known through the sense of hearing the fact that the Galvanic circuit is closed and the current flowing, is a very desirable adjunct to an office outfit. It will often save many a dollar, and great delay and annoyance, by making it impossible for an operator to inadvertently leave his battery circuit closed, thus completely polarizing and destroying the battery. It will of course also indicate when a battery is unintentionally closed, through some defective condition of the connections, such as a "*cross*" in the wires.

What electricians call a "*buzzer*" will best serve this purpose. It is operated by a separate cell, the

circuit through it being closed by means of a fine wire electro-magnet included in the working or main Galvanic circuit,—see K, Fig. 29 and 14, Fig. 28.

RHEOPHORES OR CONNECTING CORDS, serve to establish electrical connection between the electrodes and the binding-posts of the battery. Only practical experience can give any adequate idea of the petty annoyances, loss of time, and unsatisfactory results, occasioned by the use of poor connecting cords. Those ordinarily sold by instrument-makers are, as a rule,

Fig. 12—Single Conduction Coil made of 16 strands of No. 31 copper wire, with silk braid cover.

Fig. 13—Double Conduction Coil made of 16 strands of No. 33 copper wire, with silk braid cover.

made of nothing but *tinsel*, and absolutely worthless. The best material for this purpose will be found to be the double, flexible, suspension cords, used in connection with incandescent electric lighting. These cords are made up of a number of strands of No. 30 copper wire, covered first with rubber, and then with silk. They cost but ten cents per yard, and two yards will make a pair of cords of the same length, since they are double. It is best to have cords of different colors for the two poles. Figs. 12 and 13 illus-

trate properly constructed cords, as manufactured by the New Haven Clock Co., the former a single and the latter a double conductor cord. Waite and Bartlett, of New York, also make an excellent cord. It is often necessary to have a double or bifurcated cord, which will allow of two electrodes being attached to one pole, to diminish the local action of the negative pole, or to touch upon two points at the same time, or for purposes of electro-diagnosis.

A

B Fig. 14. C

RHEOPHORE-TIPS, are also frequently the source of unsatisfactory results and experiences in the use of electricity. They should never be fastened to the cord by a simple winding of the wire around the tip, but should either be soldered to the wire of the rheophore, or fastened to it by means of a screw. The best tips upon the market up to the present, are manufactured by the McIntosh Co.,—see Fig. 14. These are adjustable, enabling the operator to repair the cords when broken or to transfer the tips to other cords without the delay of sending them to the shop. A shows one adjusted for use, and B and C, the separate parts ready for attachment to a new cord, or to a

different part of an old one. This tip, however, might be considerably improved upon by slitting up the threaded portion of B, so that the wires may be brought through this slot and wound around the base of B. Then when B is screwed into C, the wires of the conductor will be firmly clamped between B and C, thus insuring good metallic contact between the tip and the rheophore. The writer has made this improvement upon his own tips, and finds it an admirable one.

Fig. 15.—Plain Electrode-Handle, with carbon electrode attached.

ELECTRODE HANDLES, may be either *plain*, *interrupting*, *pole-changing* or *rheostatic*. The *plain* handle (see Fig. 15), should be about three inches long and one inch in diameter, being hollowed out about the middle to facilitate the holding of two in one hand, one between the first and second, and the other between the third and fourth, fingers. This handle and method will be suitable for local Faradizations of muscles. The *interrupting* handle is provided with a switch for conveniently making and breaking the circuit, and is indispensable for electro-therapeutic and

diagnostic purposes. The pole-changing handle is provided with a pole-changing switch, and is very useful in applying alternating Galvanic and Faradic * currents and in electro-diagnosis. The *rheostatic* handle has a compact rheostat mounted upon it, by means of which the operator can with one finger quickly change the strength or volume of the current, even though both hands are occupied in holding the two electrodes. It is very useful

Fig. 16.—Butler's Rheostatic Electrode-Handle, one-half actual size.

when dealing with sensitive parts, or with the organs of special sense, and in diagnostic work. The only handle of this kind known to the author is shown in Fig. 16. The simple movement of E

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* We have already pointed out the fact that the effective Faradic current always flows in one direction, notwithstanding the fact that it is, physically speaking, a to-and-fro current.

The plain electrode-handle shown in Fig. 15, is manufactured by the McIntosh Co., of Chicago.

The Butler rheostatic-handle shown in Fig. 16, is manufactured by John Reynders & Co., of New York.

around the handle throws in or out a plumbago resistance, which accordingly decreases or increases the volume of the current.

BINDING-POSTS, are devices mounted upon batteries and the various instruments, for the purpose of affording a ready and effective means of connecting

Fig. 17.

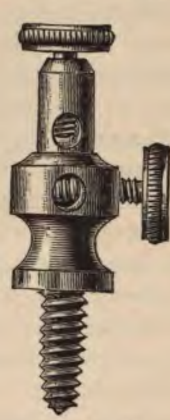


Fig. 18.

Binding-Posts.

the latter with each other and with the electrophores. Many forms have been devised, the two leading ones being shown in Figs. 17 and 18. The latter, however, will prove most serviceable for electro-medical purposes, the two holes for connections being very useful, inasmuch as it is frequently desirable to be able to make a second connection without having to re-

move the permanent connection which may have been made in the principal hole. These posts are suited to all forms of tips. These may appear to be small points, but they are very practical and useful ones.

ELECTRODES, are devices for applying electricity to the body. Too little attention has in the past been paid to the subject of the modifying influences exerted by electrodes of varying sizes and composition upon the strength of the current, and the polar, and inter-polar effects of the latter upon organic tissues. Currents of the same strength will produce widely different polar and inter-polar effects, when applied by means of different sized electrodes. The surface area of an electrode determines what is called the *density* of the current. Dry and wet electrodes produce widely different effects, both polar and inter-polar. The wet electrode produces less local irritation and carries the current beneath the skin to the deeper tissues; while the dry electrode produces more local irritation and aids in confining the current to the skin.

Electrodes are best made either of carbon (see Fig. 15) or lead. If a dry electrode is to be used, carbon is preferable; if a flexible one is desired to accommodate itself to surface inequalities, a thin sheet-lead one is to be preferred. Neither of these substances are subject to either electrolytic or chemical action, and either may be used covered or uncovered; if they are to be covered, absorbent cotton, as first suggested by Dr. Massey, will be the most cleanly

and best, using a fresh piece for each electrization. Use pure warm water to moisten the cotton—never salt water, because the salt will cause an endless amount of subsequent trouble, and prove more irritating to the cuticle. Standard sizes, as suggested by Erb, should be employed. These are as follows:

(1) Fine electrode.—½ centimetre (⅕ of an inch) in diameter:

(2) Small electrode.—2 centimetres (¾ of an inch) in diameter:

(3) Medium electrode.—5 centimetres (2 inches) square:

(4) Large electrode.—6 x 12 centimetres (2½ x 5 inches):

(5) Very large electrode.—8 x 16 centimetres (about 1¼ x 6½ inches).

Each of these should have the area of the contact-surface in square centimetres stamped upon the stem of the electrode. This outfit will suffice for all ordinary per-cutaneous applications in dermatological, myological, and neurological work.

As a dispersing and indifferent electrode in all heavy electrolytic work, as in gynæcological practice, extra large circular electrodes made of sculptor's clay (the Apostoli abdominal electrode), or of sheet-lead covered with spongio-pilen,* should be used. These should vary from 6 to 12 inches in diameter.

* An excellent electrode of this character is made by the McIntosh Co., of Chicago. It is 8½ inches in diameter.

Another form, used by the writer, may be made in the shape of a long strip to completely encircle the body, having a width of about 6 inches, and a length of 32 inches. This form is passed around the body and clasped together at the sides by means of elastic bands thrown around four lugs attached to the extremities of the electrode. This latter form is very useful in very sensitive cases requiring very strong currents, when it is not necessary to confine and localize the inter-polar path of the current.

Fig. 19.—Bi-polar Uterine Electrode. The current passes from the cup through the *cervix uteri* to the stem or pin in the centre of the cup. For either Galvanic, Faradic or induced Static currents.

Aside from these, a set of special electrodes of various forms will be required for the effective use of the active pole in the local treatment of the various parts and organs of the body, such as the eye, ear, nose, tonsils, larynx, uterus, vagina, rectum, urethra, bladder, etc.

The best designed and constructed electrodes of this character have been placed upon the market by

the McIntosh Battery Co., of Chicago, and the Waite & Bartlett Co., of New York.

A few of these, such as would prove most useful

Fig. 20.—Martin's Intra-Uterine Electrodes. These are flexible concentrating electrodes with a definite area of active surface, being designed to carry out the Apostoli treatment. The area of the active surface is stamped on each.

to the general practitioner, are illustrated in Figs. 19 to 25; only such as have been used by the writer

Fig. 21.—Bi-polar Vaginal Electrode with longitudinal division. For either Galvanic or Faradic currents; may also be used as a uni-polar electrode by connecting with a bifurcated cord.

and can be endorsed are here shown. Those which may be readily dispensed with have not been illustrated—for instance, the bi-polar uterine electrode

(Fig. 19) may serve also as a uni-polar electrode, by connecting with but one post, the circuit being com-

Fig. 22.—Bi-polar Vaginal Electrode with transverse division, may also be used as a uni-polar electrode, confining the current to either end of the vagina.

pleted through an indifferent cutaneous electrode, therefore a uni-polar electrode is unnecessary and hence not illustrated.

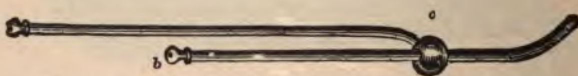


Fig. 23.—Reynder's Bi-polar Uterine Electrode. Adjustable so as to regulate the depth to which the intra-uterine portion enters.

The author's electrode case containing a choice selection of electrodes is illustrated in Fig. 25.

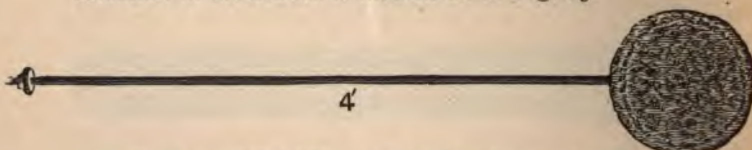


Fig. 24.—Spinal Electrode. Designed to make applications to the spine, and other portions of the body without having to remove the clothing.

Having now described in detail the separate pieces of apparatus essential for a complete *office* outfit, we must consider the assemblage and electric con-

nections of all these several pieces of electrical apparatus into one grand piece known as:—

THE ELECTRO-THERAPEUTIC CABINET. — The writer has devoted a great deal of time and spent

Fig. 25.—Hardeway's Irido-platinum Needle and Holder for the electrolytic destruction of hair follicles.

considerable money in developing what he believes to be the most complete and conveniently arranged electro-therapeutic cabinet ever constructed. Many

Fig. 26.—Author's Electrode Case.

such cabinets have in the past been designed, but as a rule they have only proved useful as elaborate pieces of office furniture for the mental impression of

patients. They have been cumbersome, inconvenient, incomplete affairs, glutted with showy but useless apparatus. In most instances these have been designed by commercial electro-mechanics without any knowledge of, or regard for, the requirements of the practical and scientific electrologist. The catalogues of the various dealers and makers always speak of them as making "showy pieces of office furniture," and that is truthfully about all that can be said in commendation of them. They generally wind up in some second-hand store or junk-shop. The complicated and absurd "*cell-selector*" is nearly always to be found in them, and the Faradic apparatus as a rule, is worthless, except to those who use electricity for the production of "*shocks*," after the manner of the street "fakir." The *so-called* measuring instrument forming a part thereof, is generally nothing but a one or two dollar pocket Galvanometer, that is absolutely worthless as an accurate measuring instrument. The most important part of all, the electrical connections and arrangement of instruments, are made without any regard to the requirements of the practical operator in electro-therapy, electro-biology and electro-pathology. The static apparatus generally fills up one cabinet that will occupy nearly the whole side of an office; while the Galvanic and Faradic apparatus fills up another and separate cabinet of equal dimensions that will occupy the other side of the office. The static machine is generally confined permanently in a case

that carries off the current and thus prevents the successful operation of the machine.

The Author's cabinet is shown in Figs. 27 and 28. It is very compact, occupying a floor space of but 34x24 inches, and only 60 inches in height. The

Fig. 27—Author's Electro-Therapeutic Cabinet, Closed.

lower enclosed portion, which is but 27 inches in height, contains the battery cells, of which there are 90, of the Law type, arranged in three tiers of 30 each. Each tier is arranged in a sliding tray that may be readily withdrawn for occasional inspection without making a single disconnection. The

upper portion, which is enclosed by a hinged glass-case with a curved front, contains the static machine and an electric motor for driving it, with all the

Fig. 28—The Author's Electro-Therapeutic Cabinet, Open

1 Am-Meter Switch.
2 Coulombmeter Switch.
3 Rheotome Switch.
5 Pole Changer.
A and B Principal Binding-Posts
6 Resistance-Box.

7 Static Machine.
8 Enclosure for Battery—Open front and back.
9 Motor.
10 Motor Switch.
11 Am-Meter.
12 Resistance Box for converting Am-Meter into Volt-Meter.
13 Rheotome.
14 Audible Indicator for Galvanic Circuit.
15 Slow Interrupter of Faradic Coil.
16 Opening and Closing Switch for Primary Circuit of Induction Coil.
17 Primary Coil of Faradic Battery.
18 Secondary Coil of Faradic Battery.
19 Current Controller.
20 Coulombmeter.
21 One of the Leyden Jars of the Static Machine.
22 Insulating Platform..
23 Cover.

necessary switches and connections self-contained; the large Du Bois-Reymond Faradic coil, with slow and fast interrupter; the Faradometer; the coulombmeter; the milli-ampere meter; the volt-meter; the current-controllor; the box of standard resistances; the pole-changer, alternator and combiner; the adjustable registering rheatome; the electrometer; the audible indicator, and all necessary switches; the whole being in such electrical connection, one with the other, that any one, or any number, or the whole, according to the desire of the operator, may be thrown into their proper relations with the entire circuit for the proper performance of their respective duties, by the simple movement of a switch, without having to make any changes in the connections, or any discon-

nections. With this cabinet, the operator may secure from one pair of binding-posts, either the Faradic, the Galvanic, the cautery, the illuminating, or the motive-power current. When not in use, the whole is enclosed under lock and key, without a single connection with the outside, secure from meddlesome children and servants, and thoroughly protected from the dust, moisture, carbon and corrosive gases of the atmosphere. When in use, the air-tight case is thrown out of the way, exposing all of the apparatus freely, so as to render all parts readily accessible for inspection and cleaning, and thus also *removing all surrounding conducting material from the static machine, the presence of which would be calculated to carry off the current as fast as generated.* Fig. 29 gives a diagrammatic illustration of the circuit connections and "*wiring*" for this cabinet. This wiring is placed upon the under surface of a separate board (*a*, Fig. 28), upon which is mounted all of the apparatus enumerated. These connections are permanently made and sealed up, never to be disturbed after being once made. The physician has to do with but *two* wires; these come from the battery, and are connected to two binding-posts upon the board carrying the apparatus. In Figs. 28 and 29, corresponding parts are similarly lettered. In Fig. 29, 5 represents the pole-changing switch, which in the position here shown makes the binding-post A positive, and post B negative; I is the ammeter switch, and when its lever, L, is in position I, the

ammeter is "*short-circuited*," or thrown out of circuit; when in position II, it is arranged for reading from the black or large current scale; when in position III, it is arranged for reading from the red or small current scale;—2 is the coulombmeter switch, and when its lever, L, is in position I, it is "*short-circuited*" (not included in the circuit, or out of use); and when in position II, it is arranged to throw in the shunt *s*, which makes it read up to 200 coulombs, and decreases its resistance; and when in position III, it is arranged to read up to 10 coulombs only;—3 represents the rheatome switch, and when its lever, L, is on o, it is "short-circuited" and inoperative in either the Galvanic or Faradic circuit; when in positions I, II, and III, however, it is operative, giving different numbers of interruptions per minute in the several positions, being thrown into either the Galvanic or Faradic circuit by means of the switch 3^a, which, when in position I, places the rheatome in the Galvanic circuit, and when in position II places it in the Faradic circuit,the contact screw being screwed down tight upon the rapid vibrator of the induction coil; 4 represents the switch for throwing in and out the volt-meter,when its lever, L, is in position I, the resistance which converts the ammeter into a volt-meter is "short-circuited," so that the instrument reads simply as an am-meter; but when the lever is in position II, the 10,000 ohm resistance coil is in circuit, and the instrument reads to 100 volts, as shown in the diagram,

it being in position to read the difference of potential across the battery, while when the lever is in position

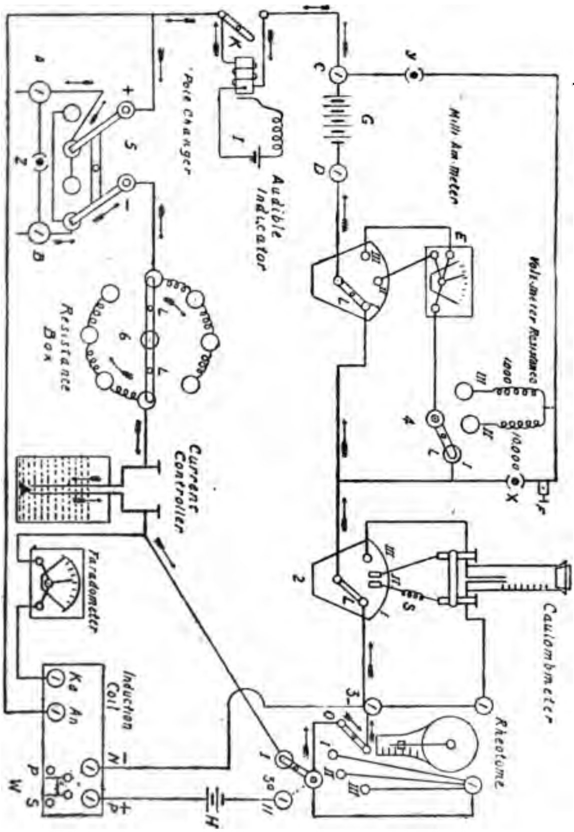


Fig. 29.

III, it reads only to 10 volts, assuming all this while that the lever L of switch 1 is in position III; 6 represents the resistance-box, and when its levers L L are in the position shown, all the resistance is cut out, but when moved in the direction of the arrows, the resistance is gradually inserted until the required number of ohms have been introduced; G represents the battery of cells for Galvanic work; H, the cell for induction coil; I, the cell for the audible indicator; N, P, the ends of the primary wire of the induction coil; Ka, An, the ends of the secondary wire of the induction coil; A, B, the principal binding posts, from which all currents are obtained; C, D, the binding posts for receiving the two wires from the principal battery; K, an electro-magnet to close the audible indicator circuit whenever the smallest amount of current flows through the main circuit; Z is a plug-hole for short-circuiting A and B; W is a switch for throwing in either the primary or secondary wire of the induction coil; X, a plug for connecting and disconnecting the volt-meter from the main circuit, so that it may at any time be rendered independent for separate use. The connections are such that any of these pieces of apparatus may be conveniently removed from the cabinet in an instant, and used for out-side practice, which is a very desirable feature, rendering but one set of apparatus necessary for office and out-side practice. Beneath the lower closed portion of the cabinet there is a space for an insulating platform to

stand, which may be removed by the foot of the operator whenever static electrizations are to be given. Thus located, this platform is always out of the way of everything when not in use, and yet easily accessible whenever required.

The writer will be pleased to supervise the preparation of such a cabinet and outfit for any physician requiring the same.

A SERIES OF EXPERIMENTS WITH THE CABINET, in illustration of its usefulness, will now be given:

1st. *For a Simple Administration of Continuous Galvanism.*—Connect the electrodes by means of the electrophores to the binding posts A and B; now place the lever L of switch No. 1 in position III, leaving all other switches in the position shown in the diagram; now place the electrode surfaces upon any desired portion of the body; observe the ammeter, and it will be seen that no current yet flows, but now gradually turn the screw-head of the current controller so as to lower the plates of carbon into the water; the ammeter will soon indicate the presence of a current. When the indicator has moved up to the figure 10 on the red scale, which is as high as this scale reads, stop lowering the plates of the current controller, and turn the lever L of switch 1 to position II; the indicator will now come back to the second division of the scale, and thus indicate 10 milli-amperes on the black scale, and the indicator could now continue up to the 500 mark, providing we continue to lower

the controller, but the pain from the current prohibits our going much further, so we will stop here. Now observing the coulombmeter, we find it to be inactive; but now move the lever L of switch 2 into position III, and little bubbles of gas immediately begin to travel upwards through the water, pressing the inner column of water down, until finally it reaches the figure 2. We have now passed two coulombs of a ten milli-ampere continuous Galvanic current through the tissues included between the points of contact of our electrodes; or, in other words, we have used a continuous Galvanic current having a strength of 10 milli-amperes for a period of 3 minutes and 20 seconds.* Suppose we now wish to measure the resistance of the tissues that have been included between the electrodes. We simply cut the coulombmeter out by replacing lever L of switch 2 to its original position, and now turn the levers L L of switch 6, in the direction of the arrows, until we have included all our resistance; next we remove the electrodes and place a plug in Z, thus connecting A. B. directly; we now gradually withdraw the resistance by moving the levers L L in the opposite direction until the indicator of the ammeter again stands at 10. The amount of resistance now left in, which may be read off

* To change the polarity of the electrodes, we have only to move switch 5 to the right or left, according as we wish to make A or B positive.

directly by observing the position of L L 6, will indicate the resistance of the tissues, plus the resistance of our circuit. The latter is now measured by replacing L L 6 to their original position, as shown in diagram, thus taking out all of the resistance coils, observing the reading of the ammeter, and then reintroducing resistance until a current of one-half the strength is indicated. The resistance now included will be equal to the resistance of our circuit, and if this be now subtracted from the first finding, we shall have the exact resistance of the tissues or body upon which we have been operating. Multiplying this resistance by the current strength (which was ten) and dividing by 1000 because a milli-ampere is one-thousandth part of one ampere, we *should* have the difference of potential in volts across the points of contact of the electrodes. To prove this and then see if our measurements and calculations have been correct, place the electrodes as before, and connect one end of a second pair of electrophores with them; connect the other ends of these with binding-posts F and E, and remove the plug X, the switch L4 being in position II; the volt-meter will now indicate the difference of potential in volts across the electrodes, and if this is equal to the product of the resistance multiplied into the strength of the current, then we know that there has been no error and that our observations and calculations are correct.

Suppose that in applying the current in the first

instance, we kept lowering the controller more and more until it was completely lowered, and yet the proper amount of current did not appear from the indications of the ammeter. This would indicate either an excessive amount of resistance somewhere in our circuit, or, a deficient electro-motive force in our battery, and the question now arises, how shall we locate or differentiate the trouble. We have only to place L 1 in position III, and L 4 in position II, and push plug X into Y; our volt-meter will now indicate the electro-motive force of the battery in volts, and if this is at least equal to one volt per cell, we may be certain the battery is all right and that the trouble is in the resistance of our circuit, which we must then proceed to measure, first in entirety, then in sections, in the manner already described.

2nd.—*To Administer the Intermittent Direct Galvanic Gurrent.*—Place same electrodes as before, see that plug Z is removed, place LI in position II, and allow all other switches to remain as shown in diagram; now gradually turn the current controller until the desired strength of current is obtained, then move L 3 from o to the proper position to give the required number of interruptions per minute, in the meantime watching the ammeter and regulating the current with the controller; when the mean throw of the needle indicates the desired strength of current, cut out the ammeter by moving switch L1 to position I; we now have a direct intermittent Galvanic current of any desired character.

3rd.—*To Secure an Illuminating Current.*—Cut out all measuring instruments, the audible indicator magnet K, and all other resistances, except that of the current controller; next connect a double electrophore as shown in Fig. 13 to the binding-posts A and B, connecting the other ends of the cord to the incandescent lamp it is desired to operate, and gradually lower the current controller. We will now have a current that will operate any incandescent electric lamp from ½ to 16 candle-power; a 3 candle lamp being, however, the one generally used in illuminating instruments. The yellow-white point of incandescence should never be passed. A blue-white light means death to the lamp.

4th.—*To Secure a Motive Power Current* to operate the electric motor for running the static machine: The motor is supposed to be a 110 volt shunt wound machine, requiring a current of but $\frac{1}{10}$ of an ampere and giving about $\frac{1}{16}$ of a horse-power. Cut out all resistance and measuring instruments as before, turn on the motor switch upon the motor, and now gradually lower the current controller. The motor will now soon begin to revolve.

5th.—*To Secure an Alternating Galvanic Current.*—Arrange things as in the first experiment and place the electrodes; now move the switch 5 backwards and forwards, after first turning on the required strength of current. We thus secure an alternating Galvanic current of any desired strength.

To Get a Simple Secondary Faradic Current with Rapid Interruptions.—See that all the switches are as shown in the diagram, with the exception of switch 3A which is to be turned into position II, and switch W, which is to be turned to position S, which gives the secondary current. Now see that the secondary coil is removed from over the primary one. Next place the electrodes in position, after having connected them with A and B, and proceded to lower the controller. Observe the Faradometer, and if, after completely lowering the controller, the current has not reached the desired strength, then proceed to move the secondary coil further over the primary one, until the desired current is indicated by the Faradometer. Should we now wish a lower electro-motive force or a current from the primary coil, we have only to raise the controller, move the secondary coil completely over the primary one, and then shift switch W to the left. Now proceed as before, first lowering the controller and then gradually moving the secondary coil from over the primary one. To change the polarity of the electrodes, shift switch 5. To produce any required definite number of intermissions to the rapidly interrupted Faradic current, turn the lever L of switch 3 to the proper position, and start the vibrator. To produce a series of rythmical induced impulses, it being required to know the number per minute, screw down the contact screw tight upon the rapid vibrator of the coil, and adjust the rheotome as desired, and the required current will be produced.

7th.—*To Measure the Resistance of any Outside Piece of Apparatus.*—Connect the object to be measured to the binding posts A and B, and proceed as described when speaking of the measurement of the resistance of tissues.

8th.—*To Measure the Electro-Motive Force of Any Outside Source of Electrical Supply*, or the difference of potential across any outside object.—Connect the object with posts D and F, see that the plug is removed from both X and Y, and then proceed to move switches L1 and 4 to their proper positions according to the character of the potential to be measured.

It is utterly impossible in this small book to begin to tell what can be done with such a cabinet. The author only hopes his efforts in this direction will not be ridiculed as ultra-scientific by those who, through insufficient information, fail to appreciate their value.

MOTIVE POWER for driving the static machine, operating surgical saws, trephines and drills, shown in Figs. 30 to 34, and the air-pump used in compressing air for medicated sprays in eye, ear, nose, and throat work, will be best supplied by an electric motor. It will prove more convenient, more cleanly, and more economical than any other form of power, providing a good type and make of motor is secured. A poor motor will prove a source of much annoyance. All things considered, electrical and mechanical construction, efficiency, convenience of starting, stopping and regulating speed, the Crocker-Wheeler motor will

be found to be the best type and make upon the market at the present time, and there is not much prospect of its being very greatly improved upon in

FIG. 30.

the near future. This statement is made upon a thorough knowledge of the principles involved in the

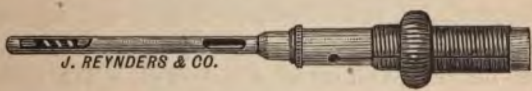


FIG. 31.

construction of all types and makes of electric motors, and a practical acquaintance with all the leading motors upon the market. This motor is shown separ-

FIG. 32.

ately in Fig. 35, and is also shown in Fig. 28 in connection with the author's cabinet, where it is seen in position for driving the static machine. To use it for

driving the nasal burrs and trephines shown in Figs. 30 to 34, we have only to attach a flexible shaft, similar to that used upon dental engines, to the front end

FIG. 33.

of the shaft (O, in the figure), where it will not interfere with its connection with the static machine. When not put to either of these uses, a fan may be

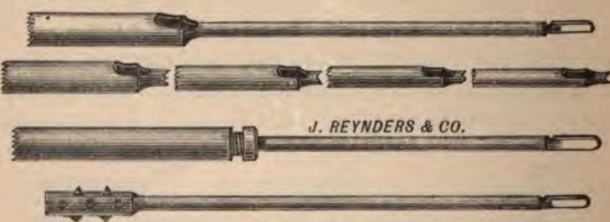


FIG. 34.

Figs. 30 to 34:—Olive-shaped, globular, cylindrical, and conical nasal burrs, trephines and saws that may be operated by the electric motor.

slipped on at O, and used to generate a refreshing breeze throughout the office. The motor should be 1-16 horse-power.

THE CURRENT TO DRIVE THE MOTOR may be had from either a primary or storage battery, or from the street electric light mains. If suitable electric light mains are in the neighborhood, this method is *decidedly* the best and cheapest. There are several kinds of mains, however, and before ordering a motor, the following information must be secured. Find out:

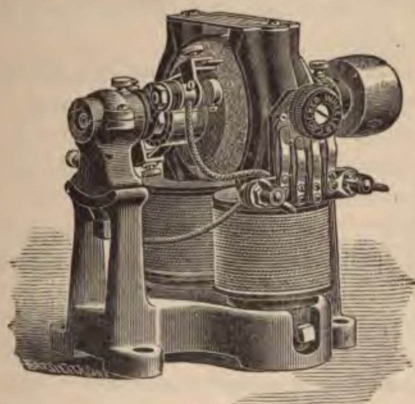


FIG. 35.—The Crocker-Wheeler Perfected Motor, ⅛ horse-power. Shunt-wound for constant potential circuits. Manufactured by C. W. & Co., New York City.

1st. If there are any electric mains in the immediate neighborhood of the office in which the motor is to be placed, and if the Company will run a wire into the office for an income of from one to three dollars per month:

2d. The character of the available mains—whether they are "*constant potential*," or "*constant current*:"

3d. What the *potential* is in *volts*, if the available mains are of constant potential; and what the *current* is, in amperes, if they are constant current mains:

4th. If the available mains are energised both day and night:

5th. If the available mains are energised with a "*direct*," "*continuous*," current, or with an "*alternating*" current.

This information will be necessary in order to determine upon the form of motor to order. A motor that would be suitable for one of these several kinds of currents, would be entirely inoperative in connection with any one of the others.

Constant potential mains are *generally* used in connection with the distribution of the little glow lamps, known as "*incandescent*;" while constant current mains are *generally* used in connection with the large intense lights known as "*arc*" lamps.

The motor must run at constant, uniform speed, independent of the varying loads which may be placed upon it. In order to effect this, one form of winding and regulation is adopted for the constant potential mains, and another one for the constant current mains. What is known as a "*shunt*" wound motor must be used for the constant potential mains;

and what is known as a "series" wound motor in connection with an automatic brush regulation, must be used for the constant current mains. The constant potential is greatly to be preferred, for very many reasons. These mains generally have a potential of either 50, 110 or 220 volts. If it is found, then, that the available main is energized during the desired office hours, and that it has a constant potential of 110 volts. Order a 110 volt "*shunt wound*" motor of $\frac{1}{8}$ horse-power. The motor shown in Fig. 35 is such a motor. It is self-regulating. To connect it to the main, run two No. 16 "office wires" from the two poles of the motor and connect them, one to each of the main wires, as they enter the house. A lightning arrester similar to that shown in Fig. 36, should be connected with each wire just before it enters the house. Somewhere in the circuit, conveniently located, there should also be inserted what is known as a "*fusible plug*," designed to carry not more than 1½ amperes. These latter are simply strips of lead that will fuse and break the circuit when a current of greater volume than the motor is designed to carry enters the office. These precautionary measures are necessary for the preservation of the motor and the protection of the office from fire. With these, an accident will be impossible.

The constant current mains generally carry from 9 to 11 amperes and have a voltage ranging from 500 to 3000 volts. These mains are dangerous to

life, and must be handled *very* carefully. All parts of the circuit within the office must be thoroughly insulated, and the bare wires should *never* be touched.

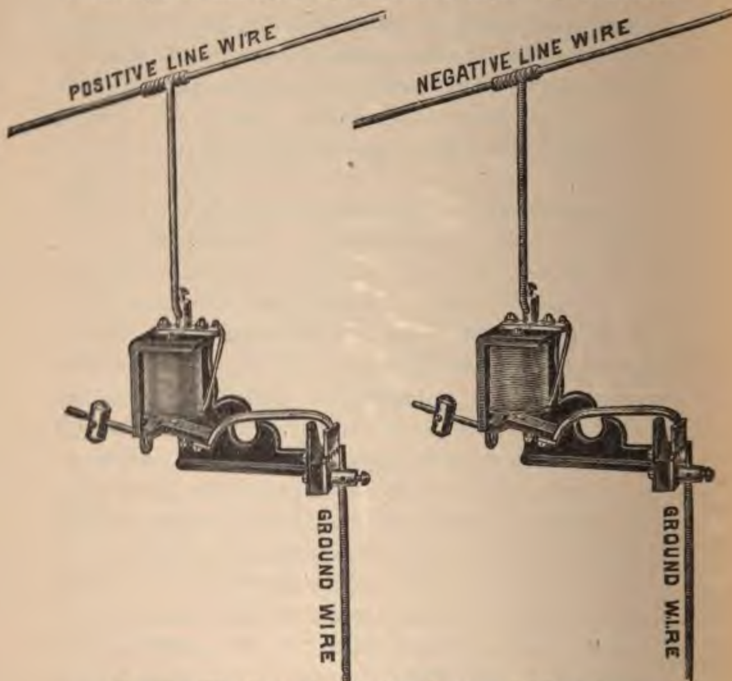


Fig. 36.—The Sperry Lightning Arrester. Manufactured by the Sperry Electrical Co., Chicago.

A lightning arrester will be necessary here also. The fusible plug, however, must be dispensed with, and its

place occupied by an "*automatic cut-out switch*," to establish a short circuit around the motor in case of a break somewhere in the motor circuit, thus saving the continuity of the circuit. Without this latter device, the physician might occasionally be the means of putting out all of the lamps on the circuit, which would be likely to cause the company to remove his wire; besides, a fire might be caused by such an accident. If the mains carry a ten ampere current, then order a ten ampere "*series-wound*" motor with automatic brush regulator for maintaining constant speed.

The "*alternating*" current will seldom prove useful to the physician, because he can neither charge a storage battery nor run an ordinary motor with it. Cautery knives may, however, be operated directly.

In case of a temporary "*shut-down*" at the central station, either the 50 or the 110 volt constant potential motor may be operated by the 90 Leclanché cells in the author's cabinet, and these may be advantageously and most economically used at all times in those cases where the motor is to be used only occasionally for very short periods. But wherever the motor is to be used much and for long periods at a stretch, the direct supply from the constant potential mains is to be preferred.

---

*Alternating current motors have very recently been placed upon the market, but their usefulness is quite limited. They must run at a fixed speed, and they cannot start from rest with a full load.

The next best source of supply, where available mains cannot be found, or where there is no working circuit during office hours, will be found to be the "*storage*" or "*secondary*" battery. These may be

Fig. 37.—The McIntosh Storage Battery.

charged from either direct constant potential or constant current mains, preferably the former. Hence, if a current may be had from mains for only a few hours out of the twenty-four, then it will be best to purchase a good storage battery with two cells, giving

an electro-motive force of 4 volts, and capable of giving a current of at least 25 amperes, with a capacity of at least 300 ampere-hours (that is, capable of producing 25 amperes continuously for 12 hours, or one ampere for 300 hours). This battery may then be switched on to the mains and "*charged*" during the period that they are energized, and then the battery used to run the motor during the intervals. Such a battery will also operate *any* cautery electrode, but it will not operate more than a 2-candle-power incandescent lamp.

If there are no available mains in the neighborhood of the office, the storage battery may be taken to the central station occasionally to be charged; but if no very convenient means is at hand for carrying a 75-pound battery to the station, then it will be best to charge it by means of a number of cells of the "*gravity*" battery shown in Fig. 38. There should be from two to three of these for each storage cell; they should be arranged in the manner shown in Fig. 39. When the storage battery is not in use, the switch in front of the binding-posts is turned to the right, and the gravity cells thus placed in circuit with the storage cells, the positive to the positive, and the negative to the negative. When the storage battery is to be used, the switch is turned to the left, which throws out of circuit the gravity cells and connects the storage cells with the binding-posts. Both the storage and gravity cells may be placed in a neat, compact

cabinet as shown in Figs. 40 and 50. The "*gravity*," or sulphate-of-copper battery, is what is known as a "*closed circuit*" battery, and it is the only primary battery suited to the charging of secondary cells. The open-circuit cells, such as the Leclanché type, are not suited to the purpose. A rheostat should accompany this outfit.

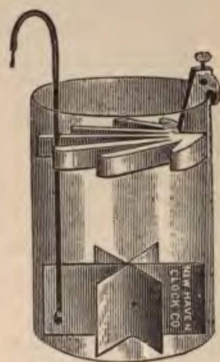
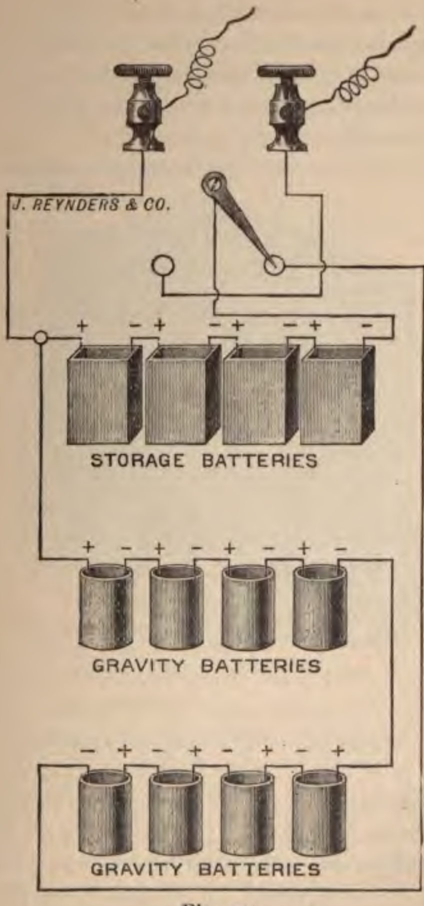


Fig. 38.—Gravity Battery of the New Haven Clock Co.

If a primary battery is to be used to run the motor, the "No. 11 cell" of Mason's primary battery, made by James H. Mason, of 118 Park Avenue, Brooklyn, N. Y., will prove the best, giving the least trouble, and proving the most economical for a primary battery. Three of these cells, such as shown in Fig. 41, will be required. Unlike most primary batteries, this one does not "*polarize*" readily, and it is


J. REYNDERS & CO.
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STORAGE BATTERIES
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GRAVITY BATTERIES

Fig. 39.

not subject to the formation of crystals within the cell, nor is it necessary to remove the zinc when the cell is not in use. Each cell has a low internal resistance, and has an electro-motive force of 2.1 volts, and will give a current of 15 amperes for 23½ hours; in other words, it has a capacity of 350 ampere-hours.

Fig. 40.—Storage and Gravity Battery Cabinet.*

It costs about 75 cents to run the motor with this battery for 12 consecutive hours of active service at full capacity (⅛ H. P.).

In ordering motors to be run by two cells of storage battery, call for a 25 ampere motor requiring an electro-motive force of 4 volts.

* Waite and Bartlett also make such a cabinet. See Fig. 50.

In ordering motors to be run by three cells of Mason's primary battery, call for a 15-ampere motor requiring an electro-motive force of 6 volts.

STORAGE OR SECONDARY BATTERIES of varied forms are upon the market, some utterly worthless, others very serviceable and economical. All storage cells have an electro-motive force of two volts. The commercial cells, as a rule, are intended to be dis-

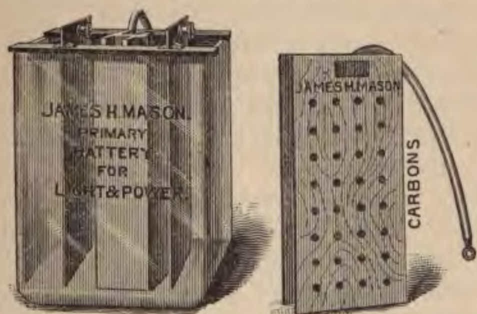


Fig. 41.—Mason's Primary Battery.

charged at the rate of from 20 to 30 amperes per hour; and they have a capacity of 350 ampere-hours per cell. Each pair of elements in a cell must have about 6 square inches for each ampere-hour of current. From these data it should be an easy matter to calculate the size and number of pairs of plates required for a battery of any required power. Of all the storage batteries upon the market at the present time, the one manufactured by the McIntosh Co., of Chicago,

will prove best suited to the requirements of the medical man. This is shown in Fig. 40. Three sizes of these are manufactured—a "small," "medium," and "large." It will prove poor economy, however, to purchase any but the large size. These have two cells, producing an electro-motive force of 4 volts, and having a capacity of about 100 ampere-hours. They are provided with a rheostat which enables the operator to regulate the current to a nicety. They will operate any cautery electrode from the smallest to the largest, or they will run a low resistance motor. In dealing with a storage battery, the greatest care must be exercised to avoid short-circuiting it—that is, bringing the poles or the cords attached thereto in immediate contact. If this should happen, the battery may be almost immediately discharged, and perhaps ruined. Its potential should be occasionally tested with the volt-meter, and as soon as the normal electro-motive force begins to show a falling off, the battery should be recharged. It should never be discharged at the rate of over six amperes per square foot of active or anode surface.

Not over thirty per cent. of the full capacity should be withdrawn before recharging.

The electro-motive force should never be allowed to fall below 1.9 volts. After the electrolyte is once put into the cell it must not be allowed to stand without a charge. It must never be charged at the rate of over three amperes per square foot of anode surface.

A disregard of these injunctions will result in injury, and may cause a complete destruction of the battery. Full directions for charging accompany each battery, hence there is no necessity for a discussion of that point here.

CAUTERY ELECTRODES have been designed in great variety, as regards form and special adaptation to the various parts of the body. They are all made of copper wire tipped with platinum.* Those with a large surface or cross-sectional area of platinum require a large volume of current, while those with less surface or cross-sectional area of platinum require less current. The large loops of wire forming the snares, require comparatively less volume, but a higher electro-motive force.

Electrodes designed for the nose and throat should be quite light and slender; those made by J. Reynders & Co. being the best. See Fig. 42. The handles for these should also be very light and compact, as shown in Fig. 43.

A variety of excellent cautery electrodes for general surgical work is shown in Fig. 44. These are made by Mc Intosh, who also makes a very good cautery snare and universal handle, shown in Fig. 45. Other forms of handles, either of which are good, are shown in Figs. 46 and 47. Extra heavy

* A current of from 5 to 40 amperes, according to the size of the tip, passed through these electrodes will render the platinum tip incandescent.

electrophores or connecting cords will be required for all the large cautery electrodes. The tips should always be brought up to a white heat before being brought in contact with the tissues to be destroyed or

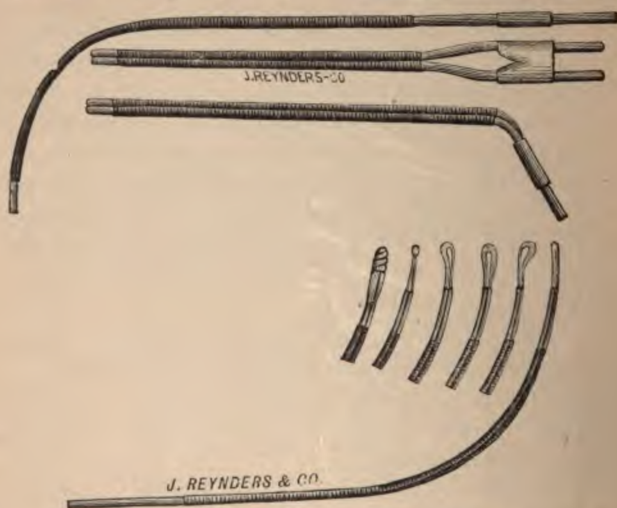


Fig. 42.—Cautery Electrodes for operations upon the nose and throat.

excised. After the tip is imbedded in the tissues, the current should be slightly increased, but great care must be exercised lest the tip be fused.

A Primary Cautery Battery is very necesary for all work outside of the office, because they are lighter and more portable than the storage batteries. The

the " C and C " Battery, illustrated in Figs. 48 and 49. It has two cells, with a combined electro-motive force best and cheapest battery suited to this purpose, is

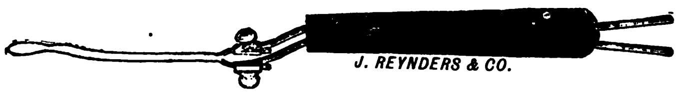


Fig. 43.—Small Handle for Nose and Throat Electrodes.

of 3.9 volts, a resistance of .06 to .15 of an ohm, and produces a current of from 30 to 45 amperes. The

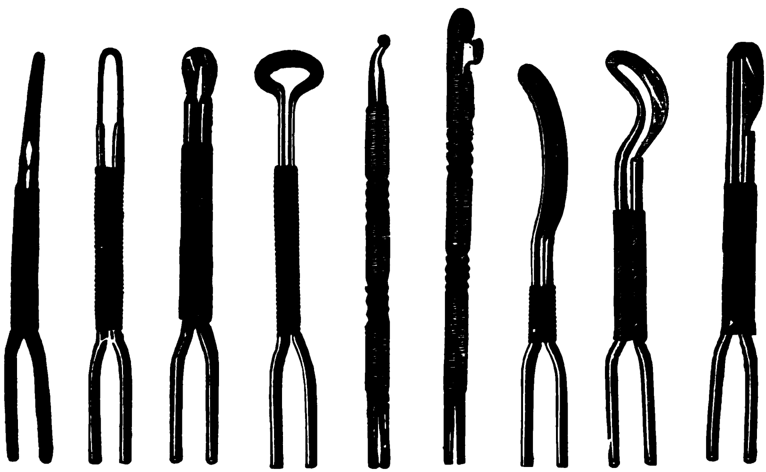


Fig. 44.—Cautery Electrodes for General Surgical Work.

complete battery weighs but 20 pounds, its size being 8x12x12 inches. The two cells are in series, and the elements are balanced by a spring, so that by means

of a lever on the outside of the box, these may be immersed in the solution to any required depth. By lowering the elements into or raising them out of the solution, the strength of the current is increased or

Fig. 45.—The Mc Intosh Cautery Snare and Universal Handle.

diminished at will. This battery may also be used for running a small low resistance motor, but it is not the best for this purpose, since it polarizes rapidly

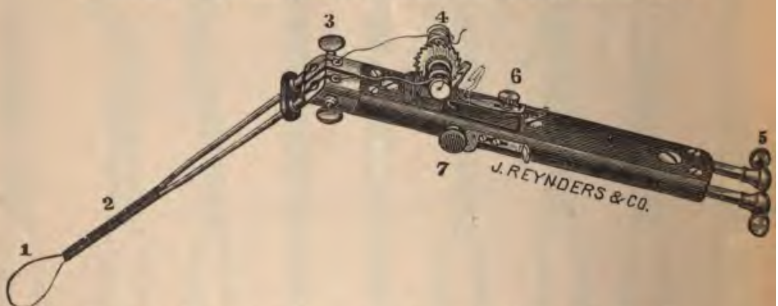


Fig. 46.—Reynder's Cautery Snare and Universal Handle.

under a rapid and heavy discharge for any considerable continuous period, will require very frequent renewals of the fluid, and annoying crystals will form in the cells. But for light eye, ear,

nose and throat cautery work, or for all kinds of cautery work outside of the office, providing a sufficient number of cells be employed, it cannot be surpassed. The platinum electrodes may be given any desired degree of incandescence by a simple manipulation of the lever. A dry compound packed in

Fig. 47.—A Second form of Reynder's Cautery Snare Handle.

tins supplied for this battery makes it perfectly safe and easy to handle. A freshly charged battery of two cells has a capacity of 50 ampere-hours. The smallest motors ($\frac{1}{20}$ horse-power) require 10 amperes per hour, so that this battery will run one of these motors for 5 hours, but not continuously, because of the polarization before referred to.

For the heavy cautery work, such as operating the large cautery knives and long snares, four cells will be required. These batteries are made four cells

Fig. 48.

to one case, but it will be found to be best to purchase two batteries of two cells each, then the two can be taken out only when heavy work is to be performed. The two small batteries will be easier to

carry than the one large one. To operate the large cautery knives, the two batteries should be coupled up in parallel for great volume, while to operate the

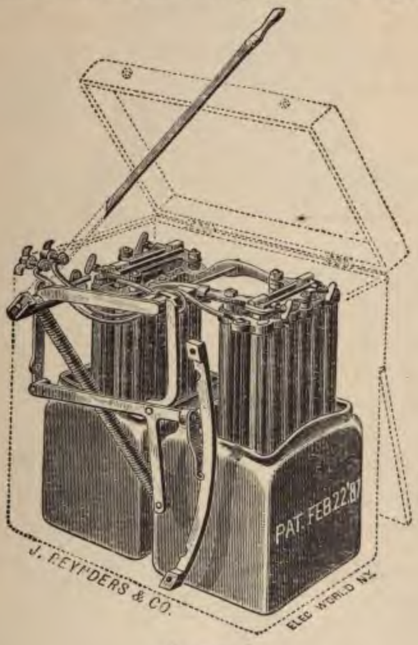


Fig. 49.

long snares, they should be coupled up in series for high electro-motive force. From the four cells, either double the volume or double the electro-motive force of the two cells may be had, according to the manner

of coupling them up. The battery of two cells will barely operate a ½ candle-power lamp, but four cells will operate as high as a 6 candle-power lamp, which requires from 6 to 7 volts. These batteries may be obtained for only $13 per pair of cells contained in a nice hard-wood box, as shown in the illustration—Fig. 48.

In operating motors for driving drills, etc., and static machines, and in operating exploring lamps and cautery electrodes, where both hands of an operator may be employed, it is very desirable to have a floor-switch arranged in the manner shown in Fig. 50, whereby the work may be started and stopped by means of the operator's foot. It is still more desirable to have this switch a rheostatic one, which will enable the operator to not only stop and start the work, but will also enable him to regulate the speed of the motor or the degree of incandescence of the exploring lamps and cautery electrodes, by a movement of the foot. A device which may be utilized for such purposes is shown in Fig. 51. It may be had of the Detroit Electric Motor Co., Detroit, Mich. An ordinary resistance box, the wires of which must be capable of carrying 40 amperes, is to be placed upon the back of the upright portion, and connected up with the series of plates forming the switch. The upright portion may be disconnected from the foot attachment at any time and operated by hand. This will prove suitable for

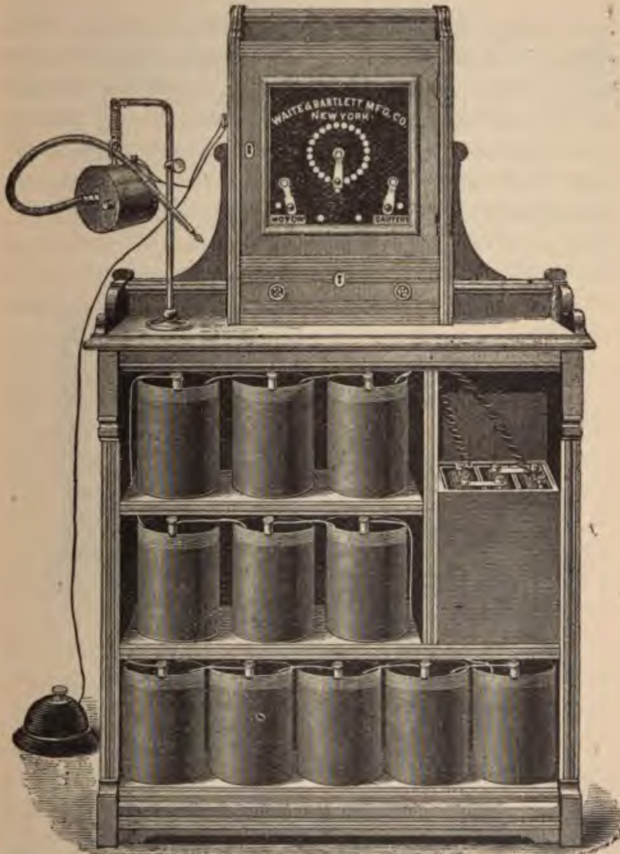


Fig. 50.—Method of Introducing Floor-Switch for Foot-Control of Motors, etc.

controlling the current from street mains, from storage batteries, or from any primary *"open-circuit"* battery, such as the Mason for example. It is connected with the circuit in the manner shown in Fig. 50. Pressure with the foot lowers the switch-lever and thus removes resistance from the circuit; the spring bringing the switch-lever back to its original position, when the pressure is removed.

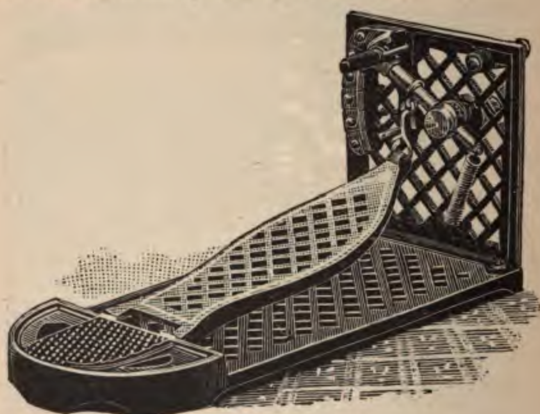


Fig. 51—Rheostatic Foot Switch.

ELECTRIC EXPLORING INSTRUMENTS AND LAMPS. —The application of electric illumination to medical and surgical explorations, was first made by the author in 1879, the "*Electric Laryngoscope*" and the "*Electric Operating Otoscope*," being the first electric exploring instruments brought before the profession.

These instruments were invented by the author in 1879, and first described by him in the New York *Medical Gazette*, of May 22nd, 1880.* Since the introduction of these instruments, the principles of which were not patented, but freely given to the profession by the author, numerous other instruments, founded upon the same principles, for the examination of the bladder, the stomach, and the urethra, have made their appearance, with the respective titles of the cystoscope, the gastroscope, and the urethroscope. In all of these the principle is the same; a current of electricity is used to render incandescent a piece of platinum wire, or a filiment of carbon, enclosed in a glass bulb from which all of the air has been expelled. This lamp is mounted directly upon the instruments, and by means of a series of reflectors and condensors, the light thus produced is directed upon the parts to be illuminated, the image of which is then reflected back directly or indirectly to the observer. The author's laryngoscope and otoscope have not been improved upon. These are shown in Figs. 52 and 53. The lamp used in these instruments has a resistance of from 3.6 to 4.5 ohms, requires an electro-motive force of 5.5 to 7. volts, and a current strength of 1.5 amperes; giving 3 candle-power. Twenty cells of any

* See also "Rocky Mountain Medical Review," September, 1880; "Archives of Laryngology," 1880; "Medical Electricity," by Roberts Bartholow, 1881; and "Diseases of the Nose, Throat, and Chest," by E. Fletcher Ingalls, 1881.

Leclanché battery will operate them, four cells of the "C and C" battery, four cells of the Mason battery, three cells of any storage battery (where lamps of the lowest resistance are used), or any incandescent light mains, providing a suitable rheostat is used in connection therewith.

A very desirable method of employing the electric light for examinations of the mouth, superficial tissues of the eye, the vagina, the nose, and the rectum, is shown in Figs. 54 and 55. This instrument allows the free use of both hands. The weight is ½ oz. When

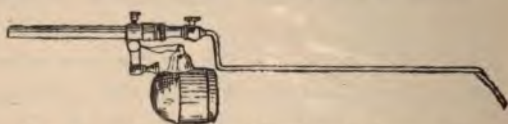


Fig. 52.—The Author's Electric Laryngoscope.

in use, it is worn the same as a pair of spectacles. Myopic and hyper-metropic operators can utilize the spectacle frame by inserting suitable glasses. Meyrowitz also makes a similar instrument with a head-band attachment in place of the spectacle frame. See Fig. 56.

The source of the electrical supply to operate this instrument, may be the same as detailed in connection with the description of the laryngoscope and otoscope.

Figure 54 illustrates the instrument complete. It is made of metal with a highly polished parabolic

mirror. The outside surface is blackened in order to prevent the reflection of light to the eyes of the operator.

Fig. 57 shows an excellent instrument for illuminating the posterior nares, while making an examination through the anterior nares; it is also very use-

Fig. 53.—The Author's Electric Otoscope.

ful in illuminating all small cavities. It can be operated with two cells of storage, the Mason, or the "C. and C." battery.

Fig. 58 shows a very good method of mounting these lamps for use in connection with the microscope.

Fig. 59 illustrates the method of applying electric illumination to examinations of the urethra. To

illustrate the cystoscope and gastroscope would be a needless repetition, since the principles are the same in all.

The different sizes of lamps used in these various illuminating and exploring instruments, in connection with all necessary data, are shown in Figs. 60 and 61.

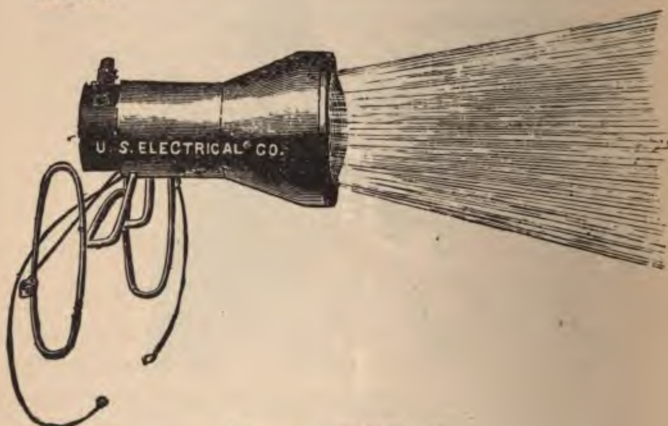


Fig. 54. (Full size).

These lamps are also very useful in connection with a Mason primary battery, for house illumination in cases of emergency—as, for instance, in night-calls, (see Frontispiece, Vol. I), when a button at the side of the bed may be pressed, and light immediately produced for dressing. On entering the hall, another button may be pressed and the hall thus illuminated. When

the front door is reached, both lights may be extinguished by pressing a third button located near the front door. Thirty dollars will purchase such an outfit, and a dollar or two per year will maintain it. What physician, having it within his means, can afford to be without the advantages and conveniences of such an outfit?

Fig. 55.—Showing the manner in which this instrument is used. The flexible battery cords are carried directly from the instrument back over the head to the battery, which can be placed in any convenient position.

A Portable Galvanic Battery that will come up to our ideal, and meet all the requirements of the general practitioner, has yet to be invented. Acid batteries are a source of great annoyance, and yet

they are the only ones thus far which will meet the requirements of the general practitioner in all classes of work. The Barrett chloride of silver open-circuit battery, which is simply a slight modification of the old Warren de la Rue battery, as manufactured by

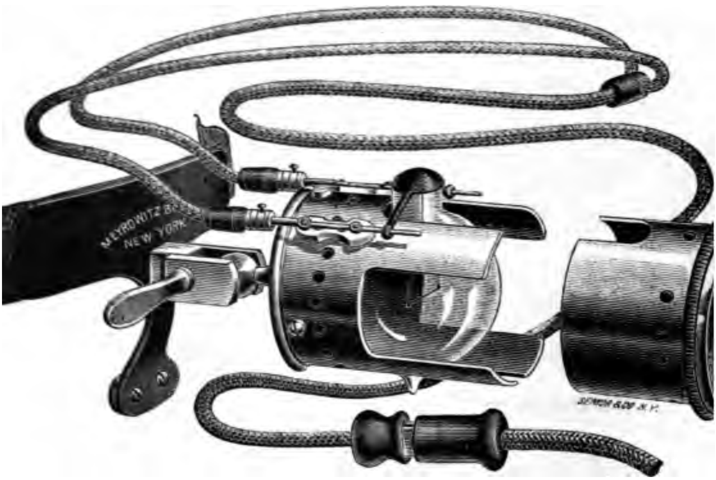


Fig. 56.

M. Gaiffe, of Paris, is undoubtedly the lightest, most compact, most cleanly, and most easily managed battery upon the market; but it has two *very serious* drawbacks, namely:

1st. It is not suited to electrolytic work and electro-chemical cauterization requiring very strong currents, such as are used, for instance, in gynæcological practice:

Since one cell will not give more than 45 milli-amperes through 11 ohms of resistance, one hundred cells in series can never give more than this— Additional cells only add to the electro-motive force so as to maintain the same current, or something less than it, through a higher external resistance, a condition of affairs due to the high internal resistance of these cells, which amounts to 7.7 ohms per cell, while the electro-motive force is only 1 to 1.07 volts; in practice, therefore, not more than 25 milli-amperes can be had from it:

Fig. 57.—Instrument for illuminating the posterior nares and other cavities.

2d. It cannot be recharged by the physician, but must be sent back to the manufacturer when it becomes discharged, which an accident may bring about at any time.

All things considered, therefore, the best portable Galvanic battery upon the market up to the present time will be found to be the McIntosh. This is shown in Figs. 62 and 63.

The electrolyte is composed of sulphuric acid and bichromate of potash, and the elements are carbon and zinc, the whole being contained in a hard-rubber

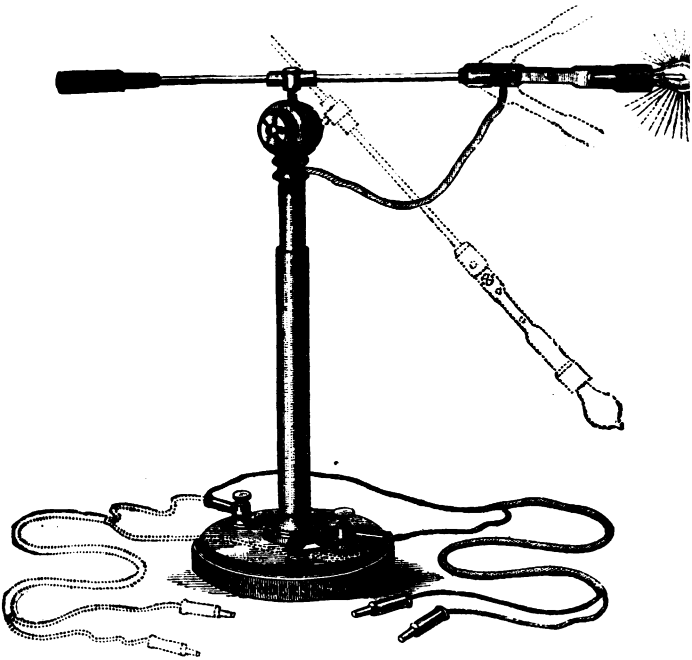


Fig. 58.—Illuminator for microscopic work.

cell. The electrolyte is placed in the small compartments shown in the foreground to the right of Fig. 62, and the elements, shown to the left of the same figure,

are inserted in these compartments when the battery is to be used. When not in use, the elements are turned around and placed in the drip-cup shown in the background to the right of the same figure. These six cells constitute one division of the battery.

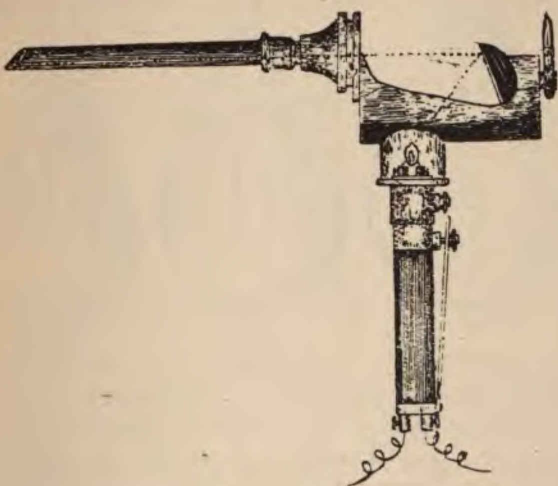
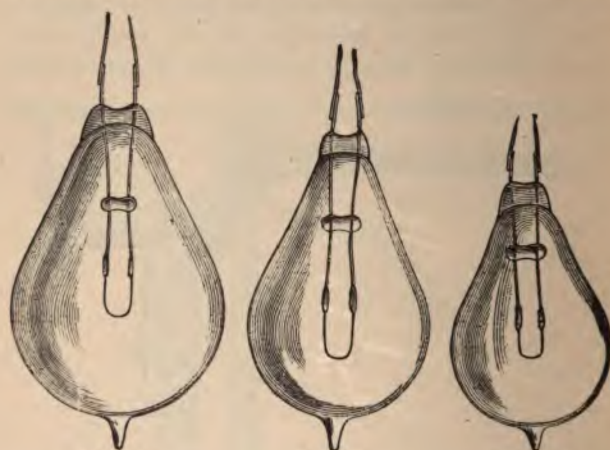


Fig. 59.—Urethroscope ready for use.

The various sized batteries are made up of multiples of these divisions, the 6-cell being but one division, the 12-cell two divisions, and the 18-cell battery three of these divisions. Fig. 63 shows a complete 12-cell battery.

For all classes of work, at least 36 cells will be required. It will be best to make them up of two



6 Candle. 4 Candle. 3 Candle.

Fig. 60.—Miniature Incandescent Electric Lamps (full size).

Power	6-Candle.	4-Candle.	3-Candle.
Price	$1.50	$1.50	$1.50
Ohms resistance........	6. to 7.	5. to 6.5	3.6 to 4.5
E. M. F. Volts required.	9. to 15.	7. to 8.5	5.5 to 7.
Amperes required	1.4	1.4	1.5

separate batteries of 18 cells each. They can be more conveniently carried about than one large 36 cell bat-

tery, and both batteries will not always be required to be carried about.

As an electrolyte for this battery, use "Mason's improved electropoion fluid" to be had of J. H. Mason, 120 Park Avenue, Brooklyn, or of the Empire

Fig. 61.

Power ...	2-Candle	1-Candle	½-Candle	Dental.	Surgical.	Pea.
Price	$1.80	$1.50	$1.50	$1.50	$2.00	$1.75
Ohms resistance.	3.3 to 5.	2.9 to 4.5	1.3 to 2.	1.1 to 3.5	1.7 to 2.5	1.5 to 2.
E. M. F. Volts required	4.5 to 5.5	3. to 5.	2. to 4.	2. to 4.	2. to 2.5	2. to 4.
Amperes requir'd	1.2	1.12	1.3	1.3	1.	1.4

City Electric Co., 15 Dey Street, N. Y. This comes in powder form, and makes ½ gallon, and costs 35cts. per package. With this fluid, there is no residue or crystal formation in the cells, and depolarization is

greatly facilitated. Bichromate of *sodium* is far preferable to the potash, as a depolarizing agent for this battery.

The 18-cell battery will weigh about 15 lbs., is 14 inches long, 8¼ inches wide and 7¼ inches high. Less than an 18-cell Galvanic battery will be of little service in medical work, except for cephalic Galvanization and work upon the organs of special sense.

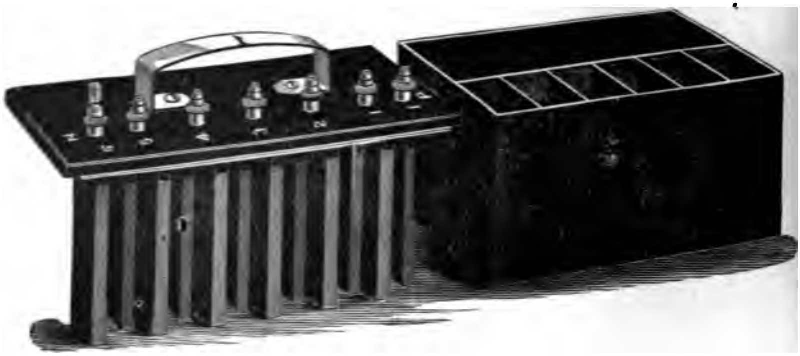


Fig. 62.—The Cells and Elements of the Mc Intosh Battery.

There is no advantage in having a "combined Faradic and Galvanic battery; in fact it is preferable to have them separate and distinct. Waite & Bartlett also make an excellent portable Galvanic battery (Fig. 64.)

A Portable Faradic Battery.—As an emergency battery for use in cases of opium narcosis, post-

partum hæmorrhages, etc., there is nothing which surpasses or even equals the Gaiffie pocket battery. One of these should always form a part of a physician's emergency satchel. These are of both American and French make. Demand the French make,

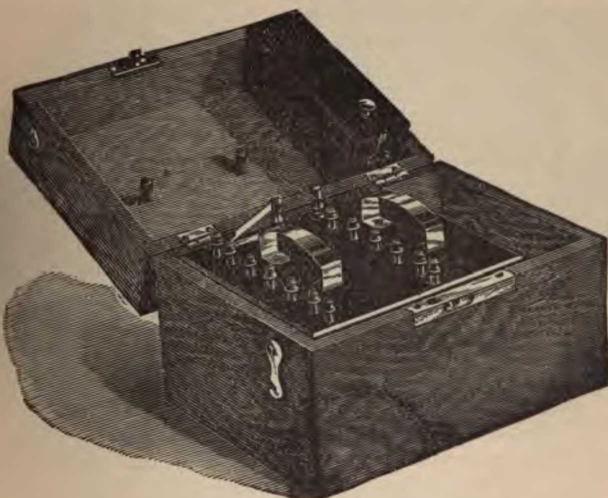


Fig. 63.—The Complete 12-Cell Mc Intosh Portable Galvanic Battery.

and accept none other. As a battery for more accurrate work suited to testing for the "*reactions of degeneration*," the treatment of paralysis, general gynæcological work, etc., the Engelmann Faradic battery

[illegible]

[illegible] remove [illegible]

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[illegible] with a wide [illegible] screw and [illegible] for producing [illegible] It is manufactured by Ware & [illegible] New York City. See [illegible]

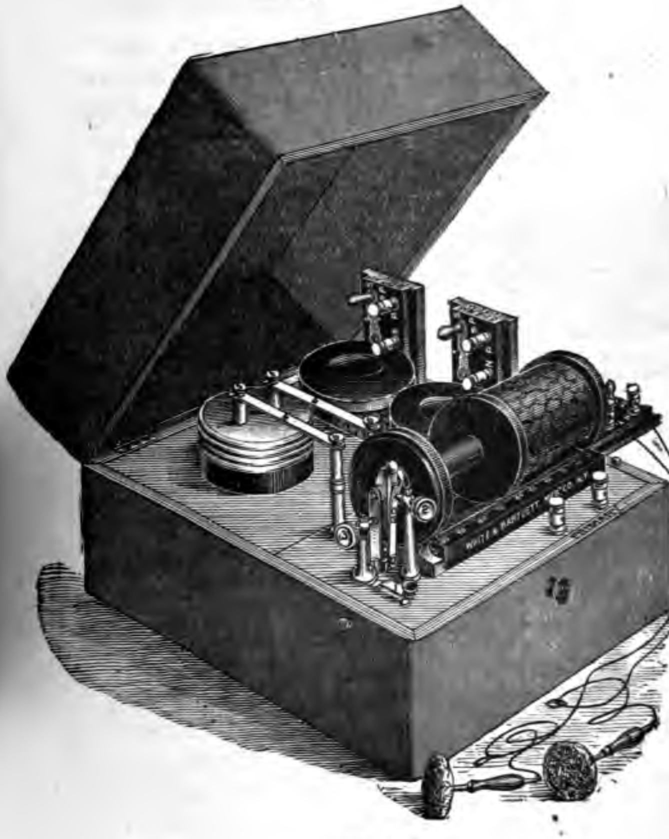

Fig. 65.

ELECTRO-MAGNETS are principally used for the extraction of particles of iron and steel from the eyes, although they have also been used as therapeutic agents; but we shall not discuss this latter subject in the present book. An excellent eye-magnet is made by Mc Intosh.—See Fig. 66.

Fig. 66.—The Mc Intosh Eye Magnet.

CHAPTER II.

ELECTRO-PHYSIOLOGY, ELECTRO-CHEMISTRY, ELECTRO-DIAGNOSIS, AND ELECTRO-THERAPY.

ELECTRO-PHYSIOLOGY comprises the study of living tissues as sources of electricity, and also of electricity as a means of influencing organic functions and modifying the excitability of normal organic tissues. The limits of the present work admit only of a brief consideration of the latter phenomena. This property of modifying excitability comprises both *nerves* and *muscles*.

Electro-tonus is the effect produced upon a nerve by the continuous passage of a current of electricity through it. A nerve under the influence of the positive pole, or *anode*, is said to be in an *anelectro-tonic* state, and a nerve under the influence of the negative pole, or *kathode*, is said to be in a *katelectro-tonic* state. Midway between the two electrodes there is a neutral point where the katelectro-tonic state merges into the anelectro-tonic state, and where, therefore, there is no departure from the normal state of the nerve. At the point, or in the part, of the nerve which is under the influence of the anelectro-tonus, the irritability of the nerve is *decreased*, while that part subjected to the katelectro-tonus has its irritability

increased. Hence it is that the anode is employed to relieve spasm by applying it over the affected nerve, in which the irritability is increased, or for the relief of painful affections, such as neuralgia, by applying it over the affected nerve, in which there is a condition of hyperæsthesia. On the other hand, the kathode is employed to increase irritability in the nerve in certain forms of paralysis, and to stimulate the vasomotor nerves, and thus increase the nutrition of atrophied muscles and other denutrified parts. These observed phenomena constitute a basis for the rational and scientific use of electricity, both as a diagnostic and therapeutic agent.

Normal Reactions.—When a current of electricity is applied to the sciatic *nerve* of a recently killed frog, the leg is jerked both at the making and breaking, or closing and opening, of the circuit. During the *continuous* flow of the current through the *nerve*, however, the muscle, except when the current is very strong, remains quiescent. The *amplitude* or violence of this muscular contraction, increases and diminishes in accordance with each increase and decrease in the *volume* of the current employed. These phenomena are known as the "*reactions*" of a *nerve* to electrical stimulus. The amount of this reaction is further influenced by the rapidity with which the volume of the current flowing through the nerve reaches its maximum. For example, a current which is very gradually brought up to a maximum volume of 5 milli-

amperes, produces no contraction, while a current of one-fifth this volume applied suddenly will produce marked contractions. The amplitude of the contractions, or the degree of intensity of the reactions, will depend upon the *pole* which is placed over the nerve, and also upon the question as to whether the electric change in the nerve results from an *opening* or a *closing* of the circuit. For example, place a moderately large moist electrode, connected with the positive pole, to some indifferent part of the body, as, for instance, over the lumbar enlargement; connect the other, or negative pole, to a small moist electrode, and apply this over the peroneal nerve at the head of the fibula. Now determine how many milli-amperes are required to produce the first visible contraction by closing and opening the circuit. Then transpose the poles, and repeat the experiment. The results will prove that a contraction or reaction will be induced with the fewest number of milli-amperes, or with the weakest current, on *closing* the circuit with the *negative* pole (kathode) lying over the nerve. This is called the "*kathodic closure contraction*," and it is symbolically expressed by the formula K C C; 2d, that the next in order will be when the circuit is *closed* and the *positive* pole (anode) is lying over the nerve, called the *anodic closure contraction* (A C C); 3rd, that closely upon its heels or along with it, will be the the contraction induced by *opening* the circuit when the *anode* is lying over the nerve—the *anodic opening con-*

traction (A O C); 4th, that with the strongest current the *kathodic opening contraction* (K O C) will be produced.

K C C will, therefore, be strong when it is obtained with the volume of current necessary to excite an A C C or A O C; and very strong with that necessary to excite a K O C. The natural sequence, thus, of the normal electrical reaction is:

K. C. C..	weakest current.
A. C. C. } A. O. C. }	medium "
K. O. C.....	.....strong "

When the electrodes are applied as above, the number of milli-amperes which will ordinarily be required to produce the first perceptable contractions under these various conditions are:

K. C. C.............	5 milli-amperes.
A. C. C.............	12 " "
A. O. C.............	26 " "

It is important to remember the general *relationship* of these values (not the values themselves, for they will vary slightly with different subjects) since this normal relationship is changed in certain pathological conditions, and hence it is valuable as an aid to diagnosis and prognosis.

It must be remembered that it is the *density of the current in the nerve* which determines the amount of excitement, and not alone the volume of the current as registered by the milli-ampere meter, and that

this *density in the nerve* is controlled by the *size* of the active electrode and the *location* of the two electrodes.

Hence it is just as important to pay attention to, and record, the size of the electrodes and their location, as it is to note the strength of the current. A current of one milli-ampere flowing from an electrode having an active surface area of one square inch, will have a density ten times as great as the same volume of current flowing from an electrode having an active surface of ten square inches. The density should be represented by a fraction, in which the value of the volume of the current occupies the position above the line, and the value of the active surface area in square inches or square centimeters occupies the position below the line, thus:

$$\frac{\text{Volume of current (in milli-amperes).}}{\text{Surface area (in square inches or centimeters).}}$$

If we send a current of one milli-ampere through electrodes having a surface area of 1, 2, and 10 square centimetres respectively, the densities of these several currents will be expressed by the fractions $\frac{1}{1}$, $\frac{1}{2}$, and $\frac{1}{10}$; and it is evident that whilst in the first case one milli-ampere will pass through 1 sq. c. m., only .5, .2 and .1 milli-ampere will pass through the same area in the case of the other electrodes. Hence, the density, which determines the amount of the chemical and physiological action of the current in the part of the body under the electrode, diminishes as the size of the latter is increased.

There is no advantage in placing the two electrodes on the skin along the course of the nerve. It is a prevalent fallacy to suppose that the *direction* of the current in the nerve exerts any special influence. In other words, it is a matter of indifference whether the current flows in the same direction as the normal nerve impulse, or in the opposite direction; so that it matters not where the "*indifferent*" electrode lies with reference to the "*testing*" electrode; it may be placed above, below, or opposite. So much for the action of the *Galvanic* current on a motor nerve.

If an "induced" current from an induction coil be applied to a motor nerve, we get a persistent "tetanic" contraction of all the muscles supplied by that nerve, instead of separate, distinct contractions. This results from the fact that the induced current is made up of a series of very short impulses, each of which acts as a Galvanic "*make*" excitation; and the "*tetanus*" is due to the fact that each successive stimulation resulting from the rapid impulses falls upon the nerve before the muscle has reached its maximum contraction and had time to relax, thus impressing a fresh stimulus upon the muscle in time to prevent its relaxation.

Healthy voluntary *muscles*, when *directly* stimulated by the Galvanic and Faradic currents, are influenced by the same conditions, and follow the same laws governing the application of these currents to motor nerves.

Each muscle has a certain "point" or points where, if the current is applied, it reacts more readily. These are called the "*motor points*," and their location for each muscle of the body must be carefully studied. Ziemmsen has investigated this question thoroughly, and proved that such points correspond to the spot where the motor nerve enters the muscle, and he has made admirable charts showing their location. When a current is directly applied to a muscle, it alone contracts; but when the current is applied to the course of a motor nerve, all of the muscles supplied by it contract. Muscles contract more easily when they are relaxed.

Involuntary muscles, instead of contracting suddenly when a Galvanic current is set up in them, and subsequently relaxing, contract slowly and continue contracting so long as the current flows, and even after it ceases. When the current is applied to the viscera, all involuntary fibres can be made to contract. When applied to the abdominal viscera of the living being, peristaltic action of the intestines is induced.

Sensory nerves give *sensory* reactions in the same manner and order that motor nerves give motor reactions, and follow the same laws with respect to the poles, etc.

Electro-Chemistry.—*Katalysis* is the term applied to indicate the *inter-polar* chemical action that occurs when a continuous Galvanic current is passed through organic tissues. This action can be demon-

strated by simply passing a current through water, when it will be decomposed into its component parts —hydrogen and oxygen; the hydrogen and any alkalies that it may contain going to the negative, and the oxygen and any acids going to the positive, pole. The same action takes place on passing a current through organic tissues, all the tissues lying between the poles being subjected to this catalytic action, as it is called.

Electrolysis, on the other hand, is a term applied to the local, or *polar*, chemical action that occurs in the tissues immediately around either one, or both, of the electrodes. In this case we have, in addition to the inter-polar disintegrating and absorbing process, a local effect of peculiar and varying character around each electrode, according to the pole used, the tissues acted upon, and, in the case of the positive pole, the material composing the electrode. If the positive pole is composed of ordinary steel, the acids which accumulate around this pole will oxidize the steel, and cause the surrounding tissues to stick to it, so that portions of the tissue may be torn away with the removal of the pole. Hence, positive electrodes designed for electrolytic use should generally be made of either gold or platinum.* The positive pole is the

* Dr. Goelet has, however, recently devised electrodes made of steel, treated in a peculiar way (de-hydrogenized), which does not oxidize under the action of the positive pole. They are manufactured by Waite & Bartlett. See Fig. 67.

more caustic and hæmostatic of the two, while the negative is the more destructive of tissue. For this reason we use the positive pole as the active internal electrode in the treatment of hæmorrhagic fibroids of the uterus, and in hæmorrhagic and leucorrhœal metritis and endometritis. The negative pole, however, being more destructive of tissue, and katelectrotonic in its action upon the vaso-motor nerves, is generally employed in the non-hæmorrhagic variety of fibroids, and in simple hyperplasia.

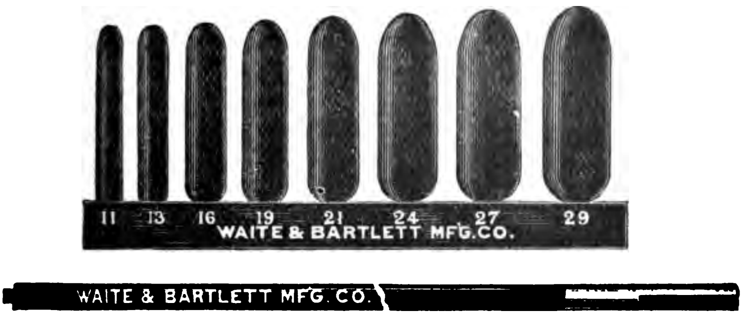

Fig. 67.

Kataphoresis, is the term applied to the movements of liquids or solutions from one electrode to the other, through animal tissues, under the influence of a Galvanic current. Munk, Von Bruns, and Adamkiewicz, were the first to demonstrate this osmotic action of the Galvanic current. They successively transmitted solutions of quinine, iodide of po-

tassium, and chloroform through the skin. In this way strychnine, cocaine, bichloride of mercury, and in fact, most any soluble drug, can be passed into the body at any point. The drug should, as a rule, be placed upon the anode, and this applied to the point it is desired to medicate; but if the special action of the kathode is desired, this pole should be placed over the affected part, the medicine heing applied to the anode. Whenever the anode is employed for the relief of pain, the efficacy is enhanced by moistening it with a ten to twenty per cent. solution of cocaine. The skin should be rubbed with a little alcohol or chloroform, before Galvanization, in order to remove all oil globules. With either cocaine or aconitine, or both combined, deep local anæsthesia may be produced sufficient for the relief of pain, or to admit of the painless performance of small operations. Anodic electrolysis in conjunction with cocaine kataphoresis, gives great relief in neuralgias and other localized painful affections. Drs. Richardson, Wagner, Adamkiewicz, Corning, and Peterson, have been largely instrumental in bringing this phenomenon of Galvanic narcotism or anæsthesia prominently before the profession.*

Absorption, is increased by the Galvanic current.

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*The Peterson electrode, made by Waite & Bartlett, will be found to be the best electrode for kataphoric purposes. All such electrodes should be made of carbon covered with some absorbent material.

The tissues and fluids which the current has decomposed are absorbed, and the natural absorption is increased; the blood-vessels and lymphatics are dilated, and the circulation of the blood and nutritive fluids is increased.

Increased Nutrition, therefore, results from the passage of a Galvanic current. This naturally arises from the increased supply of nutritious fluids. The Faradic current produces a similar effect mechanically, but not to the same extent. This effect of the Galvanic current has been very beautifully and thoroughly demonstrated by Prof. Thatcher, of Yale College, by applying the current for a week at a time alternately to the two arms of a person afflicted with paralysis, and measuring the strength of the hands at the end of each week by means of a dynamometer. It was thus demonstrated that the power increased much more rapidly in the Galvanized arm. The following is a tabulated showing of the result:

	Galvanized Arm.	Untreated Arm.
(1) Gain in strength first week (left).	17°	12°
(2) Gain in strength second week (right)....................	15°	10°
(3) Gain in strength third week (left)	7.4°	0.9°
Total....................	39.4°	22.9°

Showing that the Galvanized arm made almost double the progress of the other (1:1.72) The same person showed no evidence of gain from Faradism or massage.

ELECTRO-DIAGNOSIS, is based upon the comparison of the electrical reactions known to exist in the normal state, with those found in abnormal conditions of the nerves and muscles. Electricity in many cases affords a ready means of diagnosing structural changes, of locating pathological lesions, and of differentiating between real and simulated affections. The localization of brain functions owes its origin to electricity.

The Reaction of Degeneration (R. D.), consist of two kinds of changes: First, *quantitative*: Second, *qualitative*. The first, consists of either an increase or a diminution of the electrical excitability of motor nerves and muscles, the same being manifested by the nerve or muscle reacting to a current of less strength than in the normal state, or by contracting violently under a current which would in the normal state only produce slight contractions. The second, consists of a change in the *character* of the contractions, and also a change in the *serial* order of the "normal reactions." For instance, instead of the short, quick contractions of health, we may find the contractions slow and prolonged, which is known as a "*modal*" change, and again, the normal law of reaction to the Galvanic current is changed so that instead of kathodal closure (K. C) producing contraction with the weakest current, anodal closure (A. C.) may do so, or the two may each produce an equal contraction with the same current; or anodal opening (A. O.)

may produce a contraction before anodal closure (A. C.); all of which are known as "*serial*" changes.

Reaction of Degeneration (R. D.) *in Nerves*, consists of a quantitative diminution to both Galvanic and Faradic currents, apppearing alike, either rapidly or slowly, according to the acute or chronic character of the disease, with perhaps a final complete loss.

Rarely is there any qualitative change, and whenever there is, it is generally a modal one.

Reaction of Degeneration (R. D.) *in Muscles*, consist of both quantitative and qualitative change in the reactions of both the Galvanic and Faradic currents.

If the Faradic current is applied directly to a muscle, the latter contracts by reason of a stimulation of the intra-muscular nerve fibres, the muscular fibres not being affected directly by currents of so short a duration. The Faradic current, therefore, follows precisely the same course when applied to a muscle that it does when applied to a nerve, and the disappearance of Farado-muscular excitability is synchronous with, and dependent upon, degeneration of the intra-muscular nerve elements. Galvano-muscular excitation, on the other hand, produces very characteristic phenomena. If the morbid process be acute, there is at first a slight diminution (*quantitative* change) in response, soon followed by an increase. This peculiarity is very characteristic of facial paralysis of rheumatic origin, and in peripheral traumatic

paralysis. In such cases the rise begins during the second week, rapidly reaching a point where the weakest Galvanic current is sufficient to excite the muscle. This hyper-excitability persists for several weeks, gradually sinking back to normal or subnormal, according to the extent of the nutritive change in the muscle. In chronic cases, the diminution is the only observable quantitative alteration. The *qualitative* changes which simulaneously exist are both *modal* and *serial* in character. In many cases the sluggish, protracted, contraction wave indicative of a modal change, is the only ground upon which to diagnose reaction of degeneration. The serial changes consist principally in the overtaking of KCC by the ACC.

What, then, does reaction of degeneration signify; and what are the pathological conditions to which it corresponds? Those who undertake the practice of electro-therapy should have perfectly clear ideas concerning these points. Reaction of degeneration depends upon a specific histological modification of the irritable tissues, called "degenerative atrophy," and this degeneration itself is due to an interference with, or a stoppage of, the peculiar influence of the grey matter upon the nerves and muscles, known as the "trophic" influence. When R. D. occurs, either complete or partial, we therefore conclude that an alteration exists either of the centres themselves, or of the channels (motor fibres) which convey their influ-

ence. Erb has constructed some very instructive curves illustrative of this relationship between the reaction of degeneration, and the histological changes accompanying it.

These are in brief the main facts which constitute the underlying principles of electro-diagnosis.

The table, page 102, compiled from Erb, gives a general idea of the connection between certain pathological states and the electro-diagnostic phenomena accompanying them.

ELECTRO-THERAPY.—The general proposition that electricity, intelligently applied, is a valuable palliative, and in many cases a curative agent in the treatment of numerous morbid processes, requires no argument at this period. The only question is, how shall it be rationally and scientifically applied? This is accomplished by bearing in mind:

1st. Its property of conveying liquids from pole to pole through the tissues, or kataphoresis and osmosis:

2nd. Its property of inducing chemical changes in solutions through which it circulates, or katalysis:

3rd. Its polar chemical effect, or electrolysis:

4th. Its effects upon the circulation of lymph and blood through the tissues, directly by exciting the vessels themselves, indirectly by exciting vaso-motor and sympathetic nerves, and reflexly by exciting sensory nerves.

The Direction of the Current, may be either

SEAT OF LESION.	PROMINENT SYMPTOMS.	ELECTRICAL REACTIONS.	PATHOLOGICAL CONDITIONS AND THEIR LOCATION.
Path of impulse from the brain (antero-lateral columns); or the brain itself.	Paralysis. No muscular degeneration.	All normal.	Lateral sclerosis (idiopathic or from cerebral disease).
"Trophic centre" for the muscle, and also the path of impulse from the brain (antero-lateral columns).	Paralysis. Muscular degeneration.	*Nerve:*—Normal. *Muscle:* — Qualitative and quantitative alterations (Partial R. D.).	Amyotrophic lateral sclerosis.
"Trophic centre" extending to multipolar ganglion-cell of the anterior horn of grey matter.	No paralysis at first. Muscular (afterwards nervous) degeneration.	*Nerve:*—At first normal; afterwards diminished. *Muscle:* — Qualitative and quantitative alterations (Partial R. D.).	Progressive muscular atrophy (of central origin). Bulbar paralysis. Mild acute poliomyelitis.
Multipolar ganglion-cell of the anterior horn of the grey matter.	Paralysis. Atrophy of muscles and nerves. Abolition of reflex actions.	*Nerve:* } Reaction of de- *Muscle:* } generation.	Anterior poliomyelitis. Infantile or spinal paralysis. Lead poisoning.
Motor nerve-fibre.	Paralysis. No degeneration.	All normal.	*Light* form of "rheumatic" "traumatic," or "pressure" paralysis.
Motor nerve-fibre and path of trophic influence to the muscle.	Paralysis. Muscular degeneration.	*Nerve:*—Normal. *Muscle:* — Qualitative and quantitative alterations (Partial R. D.).	*Middle* form of ditto.
Motor nerve-fibre, path of trophic influence to *muscle*, and path of trophic influence to *nerve*.	Paralysis. Muscular and nervous degeneration.	*Nerve:* } Reaction of de- *Muscle:* } generation.	*Severe* form of ditto.
Muscular fibre.	Pseudo-paresis. Simple atrophy.	Normal, or diminution to maximal excitations.	Muscular wasting in phthisis, etc.; and in diseases of the joints. Idiopathic myositis?

"*descending*" or "*ascending*," according as it flows with or against the natural volitional impulse in motor nerves. The weight of authority has in the past ascribed the exciting or depressing effect of an electrization of a nerve to the direction of the current. This theory is, however, a thing of the past, for we now know that the direction of the current has nothing to do with determining the katelectro-tonic or anelectro-tonic influence of a current, and that this is determined alone by the pole employed as the active electrode.

The Choice of Pole, should depend upon the effect desired; as a rule applying the positive pole to those parts requiring an anodyne or sedative effect; and the negative where an excitant is needed, and in all cases where the *electro-tonic* action of the current is alone sought for. Bearing in mind, however, that wherever the expected results do not follow the use of the theoretically indicated pole, the contrary pole should be tried; and that the *katalytic* influence of a current is oftener of more importance therapeutically than its *electro-tonic* action, and that wherever this catalytic action is most promising, the alternate influence of both poles upon the affected part is indicated, not by sudden reversals of the current (*Galvanic alternations*), however, but by the gradual removal of one pole, and a gradual application of the other. In many cases the choice of pole is determined by special indications, such as the hæmostatic

or styptic, and the Galvano-caustic, effect of the positive pole, in the electrolytic treatment of certain hæmorrhagic forms of endometritis, etc. The position of the poles should, however, be determined equally as much by physical indications, so as to secure the most complete permeation of the organ or tissues, for it must be remembered that the most important point is to reach the organ with a current of the desired density.

The Choice of Current, should depend upon whether it is desired to secure a mechanical or a chemical effect. Mechanical effects are dependent upon the rate of electric change in the motor nerve, rather than upon the volume of current in the nerve, and, therefore, because of its intermittent character, the Faradic current, is best suited for the production of mechanical effects, such as the contraction of muscles and muscular tissues; while chemical effects are dependent upon the volume of the current flowing through the tissues, rather than upon the rate of change, and, therefore, the Galvanic current, because of its constancy, is best suited for the production of chemical changes, such as accompany catalytic, electrolytic, and electrophoric actions.

Not, however, because there is any inherent difference in the two currents, but simply because of the different physical conditions under which they appear, the one being *constant*, and the other *intermittent*. By using a Galvanic current of small volume and high

electro-motive force, and interrupting it with sufficient rapidity, effects may be produced identical with those of Faradism; but the latter has the advantage of being generated by a much more compact and simple device.

Fig. 68.—Pointed Electrode.—For use in connection with Electro-static Induction Machines.

The greater the rate of electric change or rise and fall of potential, and the smaller the volume of the current, the less will be the pain with equal degrees of muscular contraction. Hence it is that direct intermittent, or induced intermittent, cur-

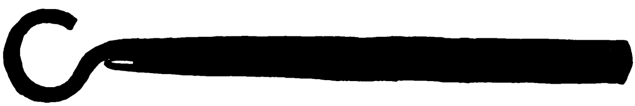

Fig. 69.—Electrophore Holder.—For use in connection with Electro-static Induction Machines.

rents of small volume and high potential, derived from electro-static induction machines, will induce more muscular contraction with less pain than even Faradic currents. The necessary electrodes and accessory implements for the application of these currents are illustrated in Figs. 68 to 73. The method of apply-

ing the direct intermittent current by means of the Morton electrode-handle, manufactured by McIntosh, of Chicago, is illustrated in Fig. 74. Waite and Bartlett, of New York, manufacture uterine, urethral, vaginal, rectal, and other useful special electrodes for this handle, and they also make one form of the latter,

Fig. 70—Ball Electrode.—For use in connection with Electro-static Induction Machines.

shown in Fig. 73. But the author does not like it as well as the one shown in Fig. 72. For per-cutaneous electrizations, where only superficial muscles are to be affected, the uncovered dry electrode will answer; but where deep muscles are to be reached, the electrode should be covered with a moistened covering. The

Fig. 71.—Roller Electrode.—For use in connection with Electro-static Induction Machines.

method of applying the induced intermittent current from electro-static machines, is illustrated in Fig. 75. In both these methods the current is regulated by changing the distance between, in the first case, the balls upon the handle, and in the second case, the balls upon the inductors of the machine. There is practi-

cally no difference in the two methods. In all vaso-motor disturbances, functional cerebro-spinal diseases or neuroses, there is nothing in the author's experience which equals in value the diffused and the concentrated constant high-potential currents from electro-static induction machines. The method of applying the *diffused* constant current is shown in

Fig. 72.—Morton's Electrode Handle.—For use in connection with Electro-static Induction Machines.

Fig. 76, and the method of applying the *concentrated* constant current is shown in Fig. 77. In the former case, the circuit is completed at all parts of the body, through the air. In the latter case, the circuit is completed by concentrating the current upon some particular part of the body by means of a spray coming from the pointed electrode shown in the illustration.

The latter method is invaluable as a general vaso-motor tonic and stimulant, as a means of restoring lost vaso-motor equilibrium, of increasing the appetite, and promoting sleep. An ordinary functional headache resulting from deficient vaso-motor tonus, or loss of equilibrium, may be relieved by this current in from two to three minutes. It is also of great and unequalled value in menorrhagia, and in suppression of the menses from cold, or shock of any kind; in muscular rheumatism, hysteria, spinal hyperæmia; and

Fig. 73.—Waite & Bartlett's Electrode Handle.

is an efficient tonic for all convalescing patients. The writer wishes to place himself on record as positively denying the correctness of the recent statements of Dr. M. Allan Starr regarding the valueless character of such currents. Dr. Starr's statements are all based upon erroneous premises regarding electro-physical laws, and are unquestionably contrary to the well established clinical observations of the writer of this book, and of scores of other practical workmen in the field.

Dosage.—The usual method of prescribing a

current of a certain number of cells, is wholly unreliable and meaningless, and should never be resorted to. Coulombmeters, volt-meters, and milli-ammeters, should take its place. It must be borne in mind that a weak current applied for a comparatively long time, behaves quite different from a stronger current applied for a short time.

Fig. 74.

Choice and Position of Electrodes.—The size and position of electrodes are essential factors. Electricity is not a fluid to be poured into the body like so much medicine, but, on the contrary, a physical and chemical *influence* that is to be exerted with a *definite intensity* upon some *definite part* of the body.

Were it not so, we might apply it in the form of the charlatanic Galvanic bath. The action of any current is, however, determined by its *density*, so that there is no more resemblance between its effects when distributed over the whole surface of the body, and when applied to a limited area, then between the

Fig. 75.

effects of a certain amount of heat diluted by the water of a bath, and the same amount of heat concentrated upon a definite region by means of a poultice or a red-hot iron. Hence the main physical conditions to be fulfilled are:

1st. That the current be of the required density, this being regulated by the size of the electrodes:

2d. That the electrodes be so placed that the desired density of current will traverse the tissues or organs to be electrized.

Electrization. – It is not "electricity" that cures, but rather, skillful "electrization," *i. e.*, the intelligent and skillful application of electricity. To say that "electricity is good" for this, that, or the

Fig. 76.

other, malady, is equivalent to saying that "medicine" is good, or that "water" is good, without specifying what kind of medicine and in what dose, or whether the water should be hot or cold, in the form of ice or steam, or applied externally or internally; for the soothing action of chloral and the exciting action of strychnine, or the soothing action of a hot bath and the exciting action of a cold douche, differ about as much as the sedative influence of a mild continuous

Galvanic current differs from the stimulating effect of an interrupted or Faradic current; the one may be beneficial where the other may be harmful. Painful currents, as a rule, do more harm than good. At the beginning of a course of treatment, great caution must be exercised in order to avoid too strong a cur-

Fig. 77.

rent. Anxiety to cure may frequently tempt one to err in this direction. Nothing general can be said as to the frequency of the electrizations. In determining the points to be electrized, the seat of the lesion and the location of the symptoms must both be considered, and the one may require a very different form of current from the other. In certain constitutional dis-

eases, or when there exists a general vital depression of nervous or other origin, it is often useful to bring the whole, or the greater part, of the body under electrical influence.

In commencing a course of treatment, and at different times thereafter, particularly in all cases of paralysis, it is very desirable to have at hand a ready means of taking a photograph of the patient, and of

FIG. 78.

the parts affected, both while in their normal condition and when reacting under the influence of the different currents, thus enabling us to more thoroughly study, record, and publish, the results of such treatment. The writer has found this to be best accomplished by the No. 64 "Kodak" illustrated in Fig. 78. To operate it, requires no special skill. It is a magazine instantaneous camera, which will take one hundred pictures without reloading. A picture is taken by simply pointing the camera and pressing a button,

as shown in Fig. 79; the manufacturers of the camera do the rest. In the localization of lesions of the brain, such a device is of great value.

FIG. 79.

There has been no effort in this book to deal with the subject of electro-therapy, except in the most general and cursory manner. The writer's only object has been to present a correct statement of the principal physical problems involved, and the apparatus employed, in the modern practice of electro-therapeutics.

The author expects soon to write another book, devoted exclusively to electro-therapy, both general and special.

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